CHEMISTRY

FOR HIGH SCHOOLS.

A. P. KNIGHT, M.A.,

THIRD EDITION.

H. A. Langford

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CHEMISTRY FOR HIGH SCHOOLS,

CONSISTING OF

A SERIES OF CONCISE DEFINITIONS, SHORT NOTES, AND CHEMICAL PROBLEMS.

ALSO,

THE ELEMENTS OF CHEMICAL ANALYSIS,

ADAPTED FOR THE

PREPARATION OF CANDIDATES FOR THE INTERMEDIATE AND
SECOND-CLASS TEACHERS' EXAMINATION

OF THE

EDUCATION DEPARTMENT, ONTARIO.

BY

A. P. KNIGHT, M. A.

RECTOR AND SCIENCE MASTER, COLLEGIATE INSTITUTE, KINGSTON, ONTARIO.

*To which are appended Examination Questions in Chemistry selected from those
recently set at Toronto, Queen's, and Victoria Universities; also,
those of the Intermediate, from 1879 to 1883.*

THIRD EDITION.

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PREFACE TO THE THIRD EDITION.

If an intelligent business man were asked to take charge of our educational system, probably the first thing he would do would be to divide the work of secondary education amongst four distinct classes of High Schools, somewhat as follows :—

I.—**Classical Schools,** whose chief object should be preparing for Matriculation in Arts, Law, or Medicine.

II.—**Normal Schools,** one in each county, whose work should consist in giving to second and third class teachers their literary and professional education. The training of first class teachers should be done in our Universities.

III.—**Technical Schools,** whose object should be the training of boys and young men for the various trades, and for mercantile life.

IV.—**Agricultural Schools,** whose special aim should be to furnish instruction in all those sciences having a direct and practical bearing on farming.

Immediately after this re-distribution of the work of secondary education, should follow the abolition of Mechanics' Institutes. As institutions for imparting technical education they have been, and are, complete failures ; and the public grant now frittered away in eking out their struggling existence, might far better be spent in establishing a new class of High Schools to do the work which these Institutes have never done, and never will do. The professions are all very much overcrowded, and therefore no special plea need here be urged for maintaining Classical and Normal Schools. But nearly 3,000 of our High School pupils leave every year to engage in mercantile, agricultural, and other pursuits, and what special training, it may be asked, has the Education Department provided for these? Scarcely any. "Our Mechanics' Institutes," I quote from the last report of the Minister of Education, "are only circulating libraries." Not quite $4,000, of the Government grant of $25,000, are spent in providing practical instruction for those engaged in mechanical employment or manufactures; and, in 1882, only 15 out of over 100 Institutes had technical classes at all. Skilled labor is one of the great wants of our country, and yet it seems to have been assumed by those who shaped our educational policy that no special training was needed by those intending to become artisans. There is, of course, an Agricultural College at Guelph, and a School of Practical Science at Toronto, but no one pretends to say that these institutions afford anything like general facilities for the acquisition of an education in agriculture or technology. To say that a classical training in our High Schools, followed by a college course in Arts, is the best preparation for business or for agriculture is simply to talk nonsense. Experience has shewn that in this country few university graduates go into business and fewer still into farming.

"The elementary rules of the farmer's art are the simplest, and the rude practices of it the easiest; yet between the worst agriculture and the best lie agri-agricultural chemistry, the application of machinery, the laws of the economy of force, and the most curious problems of physiology." * * * * * "Until the forces of nature in this land are conquered to man's use, the study of science in its various branches is an indispensable necessity. History, poetry, music, logic, moral philosophy, classical literature, are excellent as ornament; but as they must, in the present stage of our country's development, occupy the leisure part of life, so they should occupy the leisure part of education."

There is no good reason why secondary schools specially designed to teach science and technology should not be successful. Until county Model Schools were established throughout Ontario and proved successful, it was supposed that no instruction in pedagogy could be had outside of the Toronto and Ottawa Normal Schools. And until schools for the teaching of science, technology, and commerce are in successful operation in every city; and, others for the teaching of agriculture in every district, there will always be cranks and croakers who will insist that no education worth the name can be had outside of the four walls of a university. The German professors have not yet settled the case of Science *vs.* Classics. A higher court must pronounce the final decision.

Notwithstanding complaints that too many subjects were taught in our schools, the whip of public opinion has of late years compelled the addition of one modern subject after another, until at present there are some twenty-five optional or obligatory ones on the High School programme. Add to this the fact that under existing regulations each school is expected to prepare for Matriculation in Arts, Law or Medicine, for at least three grades of teachers' certificates, for admission to the Military College, for the Civil Service examinations, and lastly for Agriculture, and we have a state of affairs that might well appal any head master, even an Arnold. Amidst this terrible jumble of subjects and aims—"confusion worse confounded"—two or three teachers, in each school, bravely struggle to carry out the Departmental regulations, and especially to prepare their pupils to run the gauntlet of the examinations—honestly if possible, but through them at any cost.

If our High Schools are to continue their present rate of development—a development largely due to the energy and ability of the senior High School Inspector—the principle of the division of labor must soon be applied in apportioning the work to be done by them. A "fixed course" of study for each of our 104 schools is unnatural, unreasonable and impracticable. As every district should have its Agricultural School, so every city should have, besides its Classical School, a Technical and Commercial one, in which young men who do not desire to take a university course could be trained in English Literature, Elementary Mathematics, Chemistry, Physics, Free Hand Mechanical and Architectural Drawing, Physiology, Shorthand, Telegraphy, Book-keeping, and the Elements of Political Economy.

A. P. KNIGHT.

KINGSTON, March, 1884

PREFACE TO FIRST EDITION.

All the text-books on Chemistry authorized for use in the Public and High Schools of Ontario contain far too much matter for class purposes, and as a consequence many teachers have been compelled to teach the subject by the use of notes. This little book has been prepared chiefly for the purpose of lessening the labor of note-making on the part of teachers, and of note-taking on the part of pupils. It will require to be supplemented by explanations from the teacher, for whose use most of the ordinary text-books on Chemistry seem designed. Pupils should draw diagrams of the apparatus employed, using for this purpose the blank leaves.

No apology is necessary for the insertion of a large number of chemical problems. On the utility of these as a means of teaching the subject, Professor Roscoe says : "My experience has led me to feel more and more strongly that by no other method can accuracy in a knowledge of Chemistry be more surely secured than by attention to the working of well selected problems." On this same point Professor Cooke, a leading American chemist, says in his *First Principles of Chemical Philosophy :* "The value of problems as means of culture and test of attainments can hardly be over-estimated."

I have to express my indebtedness to Professor Dupuis, of Queen's College, for valuable suggestions in preparing this manual, and for kindness in reading the proof-sheets.

KINGSTON, February, 1882.

ERRATA.

Page 6. For "Zn = 65.5," read Zn = 65.16.
" 8. Period after "objectionable."
" 14. Omit the words "combining proportion or" in Law V.
" 15. For "diad" read "dyad."
" 16. " " " "
" 18. "*e. g.*, Fe or Cu" should be read after "hot metal," line 17.
" 20. Brackets omitted before "or" and "of" in lines 1 and 4 respectively.
" 25. Period after "acids," line 14.
" 25. For "hydrat," read "hydrate," line 15.
" 27. For "diad," read "dyad."
" 28. For "filltration," read "filtration," line 20.
" 30. For "weigh 14," read "weigh 14 grams."
" 31. For "nitrites," read "nitrides," line 19.
" 32. For "urea," read "urine," line 5.
" 32. Bracket omitted line 14.
" 32. For "turmuric," read "turmeric."

Hydric Chlorate $HClO_3$
Potassic " $KClO$
Sodic " $NAClO_3$

Preparation of ~~Hydrogen~~ Oxygen Potassic Chlorate and Manganes Dioxide MnO_2

Formula for steam - H_2O
Type of an oxide H_2O
---- a chlorine HCl
---- a Sulphide H_2S
---- a Nitrate HNO_3
---- a Carbonate H_2CO_3
---- a Sulphate H_2SO_4
---- a Phosphate H_3PO_4

~~Wt~~ Weight of air - 14.47

Latent heat of ice 75 units
" " " steam 536 units

CHEMISTRY FOR INTERMEDIATES.

The science which treats of elementary substances, the modes or processes by which they are combined or separated, the laws by which they act, as well as the properties of the compounds which they form, is called *Chemistry*.

The subject admits of a two-fold division; viz., into Organic and Inorganic.

Organic Chemistry treats of the composition and properties of substances that have been formed by the agency of animal or vegetable life. More correctly defined, it is the chemistry of the Hydrocarbons and their derivatives.

Inorganic Chemistry treats of the composition and properties of bodies formed without the agency of life. It is the chemistry of water, earth and air.

ATOMIC THEORY.—All substances are supposed to be built up of very minute and indivisible particles, called atoms. It is asserted that these atoms are of different sizes, and differ from each other in weight.

All substances can be divided into two classes—Simple substances or Elements, and Compound substances.

A **chemical element** or **simple substance** is one that has not been decomposed into two or more dissimilar bodies. Examples: gold, sulphur, and arsenic.

There are 65 of those elements; according to some chemists 69, and from one or more of these, every substance in nature is built up. The following is a list of some of the most important of them, with their symbols and atomic weights:—

Non-Metallic Elements.			*Metallic Elements.*		
			Manganese.—	Mn.	= 55
Oxygen	O	= 16	Iron	Fe	= 56
Hydrogen	H	= 1	Aluminum	Al	= 27.~~5~~3
Nitrogen	N	= 14	Calcium	Ca	= 40
Carbon	C	= 12	Magnesium ...	Mg	= 24
Chlorine	Cl	= 35.5	Sodium	Na	= 23
Sulphur	S	= 32	Potassium	K	= 39.1
Phosphorus	P	= 31	Copper	Cu	= 63.~~5~~
Silicon	Si	= 28	Zinc	Zn	= 65.~~5~~
Bromine — — —	Br	= 80	Tin...........	Sn	= 118
Flourine — — —	F	= 19	Lead	Pb	= 207
Iodine — —	I	= 127	Mercury	Hg	= 200
			Silver	Ag	= 108
			Gold	Au	= ~~197~~ 196·2
			Arsenic	As	= 75
			Antimony.. ...	Sb	= 122
			Bismuth	Bi	= 210
			Barium - - - - -	Ba	= 137
			Cadmium - - - -	CD	= 112
			Lithium - - - -	Li	= 7

The elements are usually divided into two classes, METALS and NON-METALS, there being 52 of the former, and 13 of the latter. METALS are characterized by having a metallic lustre, and some, by being malleable, ductile, &c., but no distinct line of differ-

Platinum — — — Pt 196·7

ence can be drawn between metals and non-metals. The NON-METALS, or METALLOIDS, are distinguished by the absence of these properties. Another division is 15 metalloids and 50 metals.

A **compound substance** is one formed by the union of two or more of the above-named elements. Examples—water, earth, and wood. There are thousands of these compounds known to us.

It is customary to distinguish between two kinds of compounds :—

1. CHEMICAL COMPOUNDS.

2. MECHANICAL COMPOUNDS OR MECHANICAL MIXTURES.

A **chemical compound** is one in which the elements composing it are united in such a way as to form a substance differing in properties from those of any of its constituent elements. For example, the gas chlorine and the metal sodium unite to form common salt—a substance differing in properties from those of both chlorine and sodium.

A **mechanical compound** is one in which the particles of the substances composing it lie mixed side by side, undergo no change, and preserve their distinctive properties. Example—charcoal, sulphur and nitre in gunpowder.

The force which unites the particles of a mechanical compound is called *adhesion*.

Adhesion is sometimes defined as the phenomenon which occurs when portions of dissimilar substances cling together.

Physical States of Matter.—Every substance, whether simple or compound, exists either as a solid, a liquid, or a gas. Some substances may be made to take any of these forms by varying their temperature. Ice, water, or steam is the same substance in three different physical states. So, most of the elements, and many compounds, may be made to take the solid, liquid or gaseous form by simply altering their temperature. All of the elements except carbon have been melted; all gases have been liquified, and possibly solidified.

Cohesion is the force which makes, or tends to make, bodies take the solid form. It is therefore opposed to heat. If, in any substance, these two forces counterbalance each other, the substance will take the liquid form; if the heat be the greater force, the substance will exist as a gas; and if the cohesion be the greater, the body will take the solid form.

Latent Heat.—The heat which disappears when any solid is converted into a liquid, or any liquid into a gas, is called latent heat. It is imperceptible by the thermometer, and is expended in driving the particles of a substance farther apart. On the contrary, when a gas or vapor assumes the liquid or solid form it gives out heat that goes by the name of Sensible Heat. Both terms are old-fashioned and objectionable

Distinction between Vapors and Gases.—Vapors are substances in the gaseous condition, which, at ordinary temperatures, are liquids or solids. Gases are substances which exist in the gaseous condition at ordinary temperatures.

Liquefaction is the conversion of a solid into a liquid.

Solidification is the conversion of a liquid into a solid.

Vaporization is the conversion of a liquid into a gas.

Sublimation is the conversion of a solid into a gas without liquefaction.

Condensation is the conversion of gas into the liquid or solid form.

Distillation includes, first vaporization, and then condensation, and is carried on usually for the purpose of separating a liquid from impurities contained in it.

CONSTITUTION OF MATTER.

An **atom** is the smallest part of an element that can enter into a chemical compound.

A **molecule** consists of two or more atoms, and is the minutest particle of a compound or of an element capable of independent existence. An atom cannot exist alone, but at once unites with another atom to form a molecule. The exception to this is the atom of mercury and that of cadmium.

Chemical affinity or **chemism** is the force that binds atoms together to form molecules, and molecules together to form definite chemical compounds.

Elective affinity is the attraction of one element for another in preference to a third, when there is a mixture of elements uniting to form chemical compounds.

The molecule of each element consists of two atoms; but the molecule of phosphorus as well as that of arsenic contains four atoms, while that of mercury and that of cadmium consists of one each.

Molecules of compounds contain two or more atoms.

The **Volume** of any substance is the space occupied by it. In chemistry, if no unit of volume be mentioned, it is frequently understood that *one volume of an element or compound is the space occupied by one molecule of it in the gaseous condition.*

Chemical Notation is the art of designating chemical elements or compounds by means of *symbols.*

A **symbol** is the first letter of the name of an element. Sometimes two letters are used to distinguish one element from another beginning with the same letter. The symbols of important elements will be found on page 6.

Each symbol stands also for a definite weight of each element, called its *atomic weight.*

The **Atomic Weight** of an element is the number representing how many times its atom is heavier than an atom of Hydrogen.

The Symbol of an element stands for three distinct things :—

(1) The name of the element.

(2) One atom of the element.

(3) The atomic weight of an element.

A small numeral written at the lower right hand corner of a symbol denotes that the atom and atomic weight is doubled, tripled, etc.

A **chemical formula** consists of two or more symbols written side by side, and denotes that the elements for which the symbols stand have united to form a chemical compound.

The formula of a compound substance stands for :

(1) The name of the compound,

(2) One molecule of the compound,

(3) The molecular weight of the compound,

(4) Two volumes of the compound in the gaseous condition.

A numeral placed before a formula multiplies every atom and atomic weight in it, as far as the first comma, plus sign, or period.

The molecule, O_2 consists of 2 atoms.
“ “ H_2 “ “ “
“ “ Na_2 “ “ “
“ “ P_4 “ 4 “
“ “ of the compound H_2O consists of 3 atoms.
“ “ “ $KClO_3$ “ 5 “
“ “ “ P_2O_5 “ 7 “
“ “ “ $C_{16}H_{32}$ “ 48 “

Each of these eight molecules occupies the same space or volume in the gaseous state.

A **chemical equation** consists of signs and formulæ, and expresses the fact that definite weights and volumes of certain substances do, of themselves, or by means of some force applied to them, decompose and re-arrange their atoms so as to form other substances.

For example the chemical equation—

$$\begin{array}{ccc} CaCO_3 + 2\,HCl & = & CaCl_2 + H_2O + CO_2 \\ \underbrace{100 + 73} & & \underbrace{111 + 18 + 44} \end{array}$$

may be thus translated: mix 100 grams (or ounces) of marble with a solution of 73 grams of hydrochloric acid, and they will yield 111 grams of calcic chloride, 18 grams of water, and 44 of carbonic anhydride.

All the atoms on one side of the equation must be accounted for on the other. The chemical equation thoroughly understood, enables us to calculate the amount of material required to produce a given

weight of any substance; or, the quantity of the substance produced by the decomposition of a known weight of the material. Its importance, therefore, in working out chemical problems cannot be over-estimated.

The sign +, *plus*, placed between the formulæ of two substances means that the two substances are *mixed* together.

The sign =, in chemistry, means "yields."

CHEMICAL COMBINATION.

Chemical union may take place in certain proportions by *Weight*, or when the substances exist in the gaseous condition in certain proportions by *Volume;* but in both cases the combination is regulated by certain laws called laws of chemical combination. They are usually stated as follows :—

LAWS.

I. Constant Proportion.—"The same substance consists invariably of the same elements," *e. g.*, water always consists of O and H

II. Definite Proportion.—"The elements which form a chemical compound are always united in it, in the same proportion by weight," *e. g.*, O and H are always united, in water, in the proportion of 16 to 2. By volume, the union is always 2 vols. of H to 1 of O.

III. Reciprocal Proportion.—"If two elements combine in certain proportions with a third, they combine in the same proportion with each other." For example, Cl and Na unite with O in the proportions, 35·5 and 23, respectively, with 16 of O; and in these same proportions, 35.5 to 23, with each other.

IV. Multiple Proportion.—"When one element combines with another in several proportions, the higher proportions are multiples of the first, or lowest. Thus—N_2O, N_2O_2, N_2O_3, N_2O_4, N_2O_5 = 28 : 16, 28 : 32, 28 : 48, 28 : 64, 28 : 80." There are exceptions to this law as well as to law number three.

V. Compound Proportion.—"The combining proportion, or molecular weight, of a compound substance is the sum of the combining proportions of its constituents," *e. g.*, the combining weight of H_2O is $2 + 16 = 18$.

ATOMICITY OR VALENCY.

We have already seen that the elements are divided into two classes—Metals, and Non-Metals.

There is another classification of the elements that is even more important than the foregoing. The principle underlying this second classification is the number of volumes of hydrogen that will unite with *one* volume of any other element in the gaseous condition. According to this principle all the elements may be divided into six classes. To the first class will belong all those which, in the gaseous condition, unite, volume for volume, with hydrogen. Such elements bear the name of Monads. To the second class will belong all elements one volume of which, in

the gaseous condition, will unite with two volumes of hydrogen. Such elements are called DIADS. If elements unite with three, four, five, or six volumes of hydrogen they are termed, TRIADS, TETRADS, PENTADS, and HEXADS, respectively.

The following table gives this classification in detail. It should be committed to memory.

	MONADS.	DIADS.	TRIADS.	TETRADS.	PENTADS.	HEXADS.
NON-METALS.	Bromine. Chlorine. Flourine. Hydrogen. Iodine.	Oxygen. Selenium. Tellurium. Sulfur		Carbon. Silicon.	Nitrogen. Phosphorus	Sulphur.
METALS.	Potassium. Sodium. Silver. Lithium.	Calcium. Copper. Magnesium. Mercury. Zinc.	Gold.	Aluminum. Iron. Lead. Manganese. Platinum. Tin.	Arsenic. Antimony. Bismuth.	

All the above pentads also act as triads.

Manganese and iron sometimes act like hexads, and are classified with them.

Sulphur usually acts as a diad, and forms compounds resembling those of oxygen in chemical properties.

Some of the other elements exhibit varying atomicities.

Chlorine also may be taken as the unit by which to measure the valency of elements and radicles. In fact, chlorine must be used in those cases in which there is no known compound of hydrogen and the element.

RADICLES.

A **radicle** means any substance that is the basis or common ingredient of a series of compounds. It consists of chemical elements so united as to act like one substance. For example, CO is a radicle, and called carbonyl ; OH, hydroxyl. Some radicles act as monads, some as diads, triads, &c.

METRIC SYSTEM OF WEIGHTS AND MEASURES.

This is a decimal system, hence its advantages over the English one. It was invented by the French.

MEASURES OF LENGTH.

The unit is one metre and is equivalent to 39·37 inches.

10 decimetres (dcm.) = 1 metre = 39·37 inches.
100 centimetres (cm.) = “ = “
1000 millimetres mm.) = “ = “
1000 metres (m.) = 1 kilometre = 39370·79 inches.

MEASURES OF CAPACITY.

The unit is one cubic decimetre, called 1 litre = 1·76 Imperial pints, or 61·024 cubic inches.

1000 litres = 1 kilolitre.

MEASURES OF WEIGHT.

The unit is the weight of 1 cb. cm of distilled water at 4°C, called 1 gram = 15·432 grains.

The commercial unit is 1000 grams = 1 kilogram = 2·2046 lbs. Avoirdupois.

The subdivisions of both the *litre* and the *gram* into tenths, hundredths, and thousandths, are named by prefixing deci-, centi-, and milli-, respectively to these names.

SPECIFIC WEIGHT OR DENSITY.

The specific weight or specific gravity of a liquid or solid is its weight as compared with the weight of an equal volume of water at 4°C.

In the case of gases the comparison is made with air or hydrogen.

The term **density** is another name for specific weight. It means also, according to some writers, the relative closeness of the particles composing any body.

In comparing the weights of different gases any volume of H might be taken, but the most convenient one is 11·2 litres, which, at the standard temperature and pressure of 0°C and 760 mm. of mercury, weigh 1 gram.

The weight in grams of 11·2 litres of each of the elementary gases is denoted by its atomic weight. For example :

11·2 litres of oxygen weigh 16 grams.
" " chlorine " 35·5 "
" " nitrogen " 14 " and so on.

The sp. gravity (or density) of a compound gas is found by taking half of its molecular weight. Thus:

11·2 litres of steam weigh . . . . . . $\frac{18}{2}$ = 9 grams.
11·2 " ammonia gas weigh $\frac{17}{2}$ = $8\frac{1}{2}$ "
11·2 " carbon dioxide " $\frac{44}{2}$ = 22 " and so on.

THE ELEMENTS.

Hydrogen: Symbol, H; atomic weight, 1; *molecular weight,* 2. 11·2 *litres weigh* 1 *gram.*

Sources: Nearly always found in combination. Forms $\frac{1}{9}$ by weight of water. Organic substances, Sulphuric acid, &c., contain it.

Preparation:

1. By electrolysis of water.
2. By decomposing water with a cold metal as K. Na, Ba, &c., *e. g*, $2\ H_2O + K_2 = 2\ KHO + H_2$, *e. g.*, Fe or Cu. [illegible] + H_2
3. By decomposing steam by means of a hot metal,

$$4\ H_2O + Fe_3 = Fe_3O_4 + 4\ H_2.$$

4. Hydrogen is usually prepared from zinc and sulphuric acid, the chemical change being

$$H_2SO_4 + Zn = ZnSO_4 + H_2.$$

Zinc sulphate being formed and H_2 being given off.

Experiments:

1. Burn a jet of H.
2. Pour H upwards.
3. Send up soap bubbles. Ignite some of them.

$3Cu + 4H_2O = 3CuO_4 + 4H_2$

Properties : Hydrogen is the lightest of all substances ; is a gas without taste, color or smell ; burns with a pale flame, but does not support combustion or life, though not poisonous. When mixed with half its volume of O and ignited, an explosion takes place and water is formed. Soluble in water to two per cent of its volume.

Uses :

1. In oxy-hydrogen blowpipe.
2. In gas-making from petroleum.
3. In filling balloons.

Tests : Burns, but does not support combustion ; unites with O to form water ; combines spontaneously with Cl to form hydric chloride when a mixture of the two gases is exposed to sunlight.

EXERCISE.

What weight of H can be evolved from 392 grains of sulphuric acid ?

To solve this and all similar chemical problems, pupils *must* know the chemical equations representing the reactions that take place when an elementary or compound substance is evolved from others.

The composition of sulphuric acid is :—

$$\begin{aligned} H_2 &= 2 \\ S &= 32 \\ O_4 &= 64 \\ \hline \text{Total} &= 98 \end{aligned}$$

Now the question is, if 2 grains (or oz., &c.) of H can be obtained from 98 of sulphuric acid, how many can be obtained from 392? Rule of Three: 98 (of H_2SO_4) : 392 (of H_2SO_4) : : 2 (of H) : x (of H).

Ans.—8 grains.

1. What weight of zinc sulphate and hydrogen will be formed by acting on 100 lbs. of zinc with 98 lbs. of sulphuric acid? Ans. 161·5. Ans. 2.

2. How many grams of hydrogen will occupy 224 litres at the standard temperature and pressure? Ans. 20.

3. Steam is passed through a tube containing red hot iron filings, 18 litres of hydrogen pass out at the other end. What volume of steam entered the tube, and how much are the iron filings increased in weight?

Ans. 18 litres. Ans. $12\frac{6}{7}$ grams.

4. What weight of water and potassium must be taken to produce 561 ounces (Troy) of caustic potash? What weight and volume of hydrogen will be produced?

Ans. 180 oz. Ans. 391 oz. Ans. 10 oz.
Ans. 123 cu. ft., nearly.

5. How much sulphuric acid and zinc must be taken to form 112 litres of hydrogen?

Ans. 490 grams. Ans. 377·5.

6. In ~~28·5~~ 280·5 grains of caustic potash how many grains of potassium? of hydrogen? Ans. 195·5. Ans. 5.

7. What weight of sodium must be taken to obtain 20 grains of hydrogen from a litre of water? Ans. 460.

8. A reservoir of hydrogen gas holds 89·6 litres. What weight of water will be formed in burning the gas in air? What volume of air will be required for the combustion, assuming that oxygen forms $\frac{1}{5}$ of the volume of air?

Ans. 72 grms. Ans. 224 litres.

N. B.—When the volume of gas is spoken of, it is supposed to be at the standard temperature and pressure.

When iron is put in oxygen

- $3Fe + 2O_2 = Fe_3O_4$

Preparation of Oxygen -

$2KClO_3 = 2KCl + 3O_2$

Preparation of Oxygen -:

$2H_2O = 2H_2 + O_2$

OXYGEN.

Oxygen : Symbol, O *: atomic weight,* 16 ; *density,* 16 ; *molecular weight,* O_2, 32. 11·2 *litres weigh* 16 *grams.*

Sources : Forms $\frac{1}{5}$ of bulk of atmosphere. Found combined with organic bodies and minerals, forming nearly $\frac{1}{3}$ of the weight of solid earth. Constitutes $\frac{8}{9}$ the weight of water.

Preparation :

1. By the electrolysis of water.

2. By decomposing some oxides by heat, *e. g.*, HgO, MnO_2, BaO_2, Oxygen may be obtained by heating the red oxide of mercury (mercuric oxide) in a test tube, the equation expressing the reaction being as follows :

$$2\,HgO = Hg_2 + O_2.$$

3. By heating potassic chlorate and MnO_2 in a glass retort :

$$MnO_2 + 2\,KClO_3 = 2\,KCl + 3\,O_2 + MnO_2.$$

4. Hypochlorites, chlorites, and some nitrates, will yield oxygen on being heated.

Properties : It is soluble to the extent of four per cent. in water, a fact of great importance in relation to aquatic plants and animals. When free it exists as an invisible gas without taste or smell. By cold and pressure it has been made to take the liquid and even the solid form ; it unites with all the other elements, except fluorine, to form *oxides;* powerfully supports combustion; and is that element in air which sustains animal life, hence called *vital air.* In respiration we simply take oxygen into the system, and this causes slow combustion of the tissues, and consequently gives rise to animal heat.

Experiments: Sulphur, potassium, phosphorus, charcoal, a piece of wood, steel-wire, and zinc foil, may be burned in jars of the gas. Ordinary *combustion* or *burning* is simply chemical action, attended by great heat and light, chemical compounds being formed.

Tests: Oxygen is THE great supporter of ordinary combustion. A glowing splinter of wood bursts into flame when plunged into it. Nitric oxide forms reddish fumes with oxygen. Potassic pyrogallate absorbs oxygen, and is changed to a black color by it.

OZONE.

Ozone: *Symbol,* O_3; *molecular weight,* 48.

This substance is merely a modified form of oxygen, being one in which there are supposed to be three atoms in the molecule instead of two.

Preparation:

1. By the silent discharge of electricity through oxygen. Thus treated, O decreases in bulk by ^{1}

2. By placing a stick of clean phosphorus in a bottle of air with a little water on the bottom of it.
3. It is produced in small quantities by almost any molecular disturbance of oxygen.

Properties: Ozonized oxygen has a strong, oppressive odor; corrodes india-rubber; oxidizes silver, mercury, and many other metals, and, in doing so, undergoes no diminution in volume; possesses great disinfecting powers, and is a powerful bleaching agent. If breathed in small quantities it is said to be beneficial in the treatment of affections of the throat and lungs.

Test: Ozone turns a mixture of iodide of potassium and starch a blue color, but this test is not reliable.

EXERCISE.

1. How many pounds of potassic chlorate must be taken to obtain 144 lbs. of oxygen? Ans. 367·8.

2. I want 220 grams of oxygen. If I obtain it from potassic chlorate, how much of it must I use? If from water, how much? If from mercuric oxide, how much?
Ans. 561·9. Ans. 247·5. Ans. 2970.

3. A gas bag is capable of containing 56 litres, how much potassic chlorate must be taken to procure enough oxygen to fill it? Ans. 204⅓ grams.

4. 25 litres of oxygen are exploded with 36 of hydrogen. What volume of gas (if any) remains? What volume of steam is produced? And what is its weight?
Ans. 7 litres of O. Ans. 36. Ans. ~~44·8.~~
25·

5. How much oxygen can be obtained from 435 grams of manganese dioxide by heating it to a red heat?

Ans. 53·3.

6. What volume will 80 grams of oxygen occupy at the standard temperature and pressure. Ans. 56 litres.

NOMENCLATURE.

Chemical Nomenclature is the system of naming chemical compounds.

I. In naming binary compounds, or compounds of two elements, we attach both prefixes and affixes to the names of the elements.

1. -ic is generally attached to the name of the first element.

2. -ide is attached to the name of the second element.

For example, KCl is named potass-ic chlor-ide.

-uret is an old ending, sometimes used instead -ide.

3. Compounds of oxygen with other elements, when one, two, three, four, or five atoms of oxygen enter into the compound, are, with some exceptions, called respectively mon-oxide, di-oxide, tri-oxide, tetr-oxide, pent-oxide, of the first element.

4. Another mode of designating the compounds of oxygen is by using the endings -ous and -ic, both being attached to the first element; the former, when a smaller quantity of oxygen enters into the compound; the latter, when a larger quantity. The affixes -ous and -ic are used in a smilar way to denote binary

compounds of chlorine and sulphur with other elements.

5. SESQUI-OXIDE and SUB-OXIDE are old terms.

EXERCISE.

Name the following binary compounds : NaCl, CuS, N_2O, N_2O_2, N_2O_3, N_2O_4, N_2O_5, HCl, H_2S, CO, CO_2, $CaCl_2$, CS_2, P_2O_5, CuO, HgO, K_2O, FeO, Fe_2O_3, As_2O_3, As_2O_5.

II. **Hydrates** or **Hydroxides** are compounds formed by the union of an element, or radicle, with the monad radicle OH (Hydroxyl), *e. g.* :

KHO is called potassic hydrate.

$Ca\ (OH)_2$ is called calcic hydrate.

Hydrates are divided into two great classes : ACIDS and BASES. Generally speaking, hydrates of the metals are bases, and hydrates of non-metals are acids

We can also divide oxides into acid oxides and basic oxides, according as the corresponding hydrat. is an acid or base.

Acids possess the following properties :

1. They have usually a sour taste if soluble.
2. They change blue litmus red.
3. They act upon a metal giving up hydrogen, which they all contain, for the metal.
4. They act upon basic oxides forming water, and neutral compounds, called salts.

In naming acids the terminations -OUS and -IC, and the prefixes HYPO- and PER-, are used, *e. g.* :

$HClO$ is called hypo chlorous acid.
$HClO_2$ is called chlorous acid.
$HClO_3$ is called chloric acid.
$HClO_4$ is called perchloric acid.

For the least amount of O present in the above compounds, HYPO——OUS is used ; -OUS, for more oxygen ; -IC, for still more of it ; and PER——IC, for the greatest amount.

Bases: or Alkalies

1. Have an alkaline taste if soluble.
2. Restore to blue the color reddened by an acid.
3. Have generally properties the opposite to those of an acid.

Salts, when normal, possess properties that are neither acid nor basic. They are formed by acids acting upon :

1. A basic hydrate.
2. A basic or neutral oxide.
3. A metal.
4. Theoretically, by replacing the H of an acid with a metal. For example, the acid HNO_3, with the metal K, forms the salt KNO_3.

Salts are named chiefly from the acids which form them.

If the acid end in -IC, the salt ends in -ATE.

If the acid end in -OUS, the salt ends in -ITE.

The prefix of the acid is retained in naming the salt, *e. g* :

ACID.	NAME.	SALT.	NAME.
$HClO$	hypochlor-OUS acid.	$KClO$	potassic HYPO-chlor-ITE.
H_2SO_3	Sulphur-OUS acid.	Na_2SO_3	sodic sulph-ITE.
HNO_3	nitr-IC acid.	$AgNO_3$	argentic nitr-ATE.
$HClO_4$	perchloric acid.	$KClO_4$	potassic PER-chlor-ATE.

EXERCISE.

The principle of atomicity may be employed in forming the theoretical oxides and hydrates of the metals by using water as a type, and substituting in a single molecule of water one atom of a monad metal for one atom of hydrogen to form a hydrate, and two atoms of a monad metal for the two atoms of hydrogen to form an oxide. In two molecules of water, we must substitute one atom of a diad metal for two atoms of hydrogen to form the hydrate, and two atoms of the diad metal for the four atoms of hydrogen to form the oxide. For example :

Type.	*Hydrate.*	*Oxide.*
H_2O	KHO	K_2O
$2\ H_2O$	$Ca(HO)_2$	CaO

1. Apply this principle and form the hydrates and oxides of the following metals : Sodium, silver, mercury, magnesium, iron, tin, platinum.

2. Name the compounds thus formed.

COMPOUNDS OF OXYGEN AND HYDROGEN.

These are two in number, but the only important one is water.

WATER.

Formula, H_2O ; *molecular weight*, 18 ; *sp. gr. at* 4°*C*, 1 ; *sp. gr. in gaseous state*, 9 ; *freezes at* 0°*C* ; *and vaporizes at* 100°*C* ; *point of maximum density*, 4°*C*.

Properties : It is a tasteless, inodorous liquid, of a bluish green color, and can be obtained pure by distillation only ; rain water is the product of natural distillation, but even this contains traces of carbonic acid, ammonia, nitric acid, and gases of the air.

Impurities : Spring water contains sodic chloride (salt), calcic carbonate, calcic sulphate, small quantities of magnesic carbonate and sulphate, silica and a variety of other substances.

The **solid** soluble impurities of water may be removed by distillation ; insoluble impurities, by filltration.

Liquid impurities can, as a general rule, only be removed with extreme difficulty, and never by distillation.

Gaseous impurities may be removed in large part by boiling or by filtration through charcoal or spongy iron.

The impurities in city well water are ammonia, the nitrites and nitrates of calcium and sodium, and

$CaH_2(CO_3)_2 +$ heat $= CaCO_3 + H_2O + C$

limestone $= CaCO_3$

Formula for washing soda -
Na_2CO_3

worst of all the drainage from animal refuse. Running water is fitter for drinking than stagnant, because its motion exposes a fresh surface to the air, so that oxygen is continually absorbed and oxidizes the animal and vegetable matter in the water, forming innoxious compounds.

The **temporary hardness** of water is due to the presence of calcic or magnesic carbonates in it, and may be removed by boiling or by treating with lime.

Permanent hardness is due to salts of calcium and magnesium, other than the carbonates, such as sulphates and nitrates, and may be removed by adding washing soda (sodic carbonate).

Water of crystallization is that which a salt requires in order to crystallize. **Anhydrous** substances are those free from water in combination.

Water may be decomposed into oxygen and hydrogen by means of electricity. When this is done, and the products weighed, we observe that the one volume of oxygen weighs 8 times as heavy as the 2 volumes of hydrogen produced in the process. The **synthesis** of water by the *Eudiometer* shows that 2 vols of hydrogen unite with 1 of oxygen to form two of water, hence the specific weight of water in the gaseous condition is 9. In the **analysis** of water, the one vol. of oxygen weighs 8 times as heavy as the two of hydrogen, hence vol. for vol. oxygen is 16 times as heavy as hydrogen.

Law of Avogadro.—Equal vols. of gases at equal temperatures and pressures contain the same number of molecules.

From this law it follows, that one molecule of O weighs 16 times as heavy as one of H. Hence also the atom of O is 16 times heavier than the atom of H.

The presence of any considerable amount of ammonia in water renders the advisability of using such water for culinary purposes very doubtful. Ammonia can be detected in water by applying the following test :—

Nessler's Test for Ammonia.—"To a solution of potassic iodide add solution of mercuric chloride until the precipitate formed is nearly all re-dissolved, then add an equal volume solution of caustic potash, and allow the whole to stand until clear. A few drops of this solution will give a yellowish-brown precipitate, with even the slightest trace of ammonia."

NITROGEN.

Nitrogen : Symbol, N ; atomic weight, 14 ; *density,* 14 *; molecular weight,* 28. 11·2 *litres weigh* 14

Sources : Constitutes four-fifths of air, thus diluting the O ; found in plants being a constituent of some of the strongest poisons such as prussic acid and strychnine ; components also of bread, milk and flesh of animals.

substance that will turn
blue litmus solution red
s called an acid.
$P_2O_5 + 3H_2O = 2H_3PO_4$
Question (2) $2Cu + O_2 - 2CuO$

Preparation : $P_4 + \underbrace{(5O_2 + N_x)}_{air} = 2P_2O_5 + N_x$

1. It is obtained by burning phosphorus, or some other combustible, in a bell-jar over water, the oxygen being burned out and nitrogen remaining.
2. By passing purified air over red hot copper.
3. By heating a strong solution of ammonium nitrite : $NH_4NO_2 = N_2 + 2\ H_2O$.

Experiments :

1. Show that it will not support ordinary combustion.
2. Show that it will not burn.

Properties : Nitrogen has neither color, taste nor smell ; is a little lighter than air ; will not support life ; has been liquefied by cold and pressure ; does not support ordinary combustion ; soluble in water to the extent of two per cent. of its volume. Does not unite readily and directly with other elements, except boron and titanium, to form *nitrites*.

Tests : It does not support common combustion, and is distinguished in a general way by its *negative* properties.

EXERCISE.

1. What weight and volume of nitrogen can be obtained om 448 grams of nitrite of ammonia ?

Ans. 196 grams ; 156·8 litres.

2. Assuming that nitrogen constitutes $\frac{4}{5}$ of the volume of r, what weight of cupric oxide would be formed in obtaing 84 grams of nitrogen by passing a sufficient quantity of r through a tube containing copper filings ?

Ans. 119·25 grams.

3. How many litres will 210 grams of nitrogen occupy ?

Ans. 168 li

COMPOUNDS OF NITROGEN.

Ammonia : (Spirits of Hartshorn) Formula, NH_3 ; *atomic weight,* 17 ; *density,* 8·5. 11·2 *litres weigh* 8·5 *grams.*

Sources : It occurs in the urea and in some other products of animals, also in air as the result of the decay or combustion of animal matter.

Preparation :

1. Formerly obtained by distilling portions of bone, ivory, horn, parchment, feathers, silk.
2. Now from the waste liquors produced by the destructive distillation of coal.
3. May be obtained in the laboratory by heating sal-ammoniac ammonic chloride) and quick lime :

$$2\ NH_3HCl + CaO = 2\ NH_3 + CaCl_2 + H_2O.$$

4. Most conveniently obtained by simply heating some liquor ammoniæ.

Experiments :

1. Pass the gas into a solution of turmuric, and into one of reddened litmus.
2. Show its rapid solubility in H_2O, using a narrow-necked bottle.
3. Show the white cloud produced with a volatile acid, *e. g.*, HCl.

Properties : Is a colorless gas with an alkaline taste and pungent smell ; soluble to upwards of 700

times its bulk in water at 15°C, which is then called **liquor ammoniæ**; is powerfully alkaline; becomes liquid at −40°, may even freeze at −75°.

Tests: Its smell; its solubility in water. See Nessler's test, under the notes on water.

Ammonium Hydrate, NH_4HO, *or* NH_3, H_2O.
"Liquor Ammoniæ."

This compound is formed by dissolving NH_3 in water, and is a most powerful base or alkali.

EXERCISE.

1. Calculate what volume 51 grams of ammonia gas will occupy. ANS. 67·2 litres.

2. 112 litres of ammonia gas are decomposed in a eudiometer; what volume will its constituent gases occupy?
ANS. 28 litres of nitrogen; and 84 litres of hydrogen.

3. What weight and volume of ammonia gas can be obtained from 214 grams of ammonic chloride?
ANS. 68 grams; 89·6 litres.

4. If 85 grams of ammonia gas be decomposed in a eudiometer, and 22·4 litres of oxygen gas be added to the constituent gases, and the mixture exploded, what will be the volume of the resulting gases at 0°C.
ANS. 28 litres of nitrogen; and 39·2 of hydrogen.

5. What weight of quick-lime is required to decompose 107 grams of ammonic chloride, and what will be the weight of the calcic chloride and water produced? What volume of ammonia gas will be evolved?
ANS. 56 grams of lime; 111 of calcic chloride; 18 of water; and 44·8 litres of ammonia.

COMPOUNDS OF OXYGEN AND NITROGEN.

Oxygen forms with nitrogen five known compounds:

NAMES.	FORMULÆ.	OLDER NAMES.	CORRESPONDING ACIDS.
Nitrogen Monoxide.	N_2O.	*Nitrous Oxide.*	*HNO Hyponitrous Acid* (not eliminated).
Dioxide.	NO.	*Nitric Oxide.*	
Trioxide.	N_2O_3.	*Nitrous Anhydride*	HNO_2 *Nitrous Acid* (not eliminated)
Tetroxide.	NO_2.	*Nitrogen Peroxide.*	
Pentoxide.	N_2O_5.	*Nitric Anhydride.*	HNO_3 *Nitric Acid* (well known).

The first three oxides are important. Nitric acid is also.

Nitrous Oxide ("Laughing gas"): Formula, N_2O; *molecular weight,* 44; *density,* 22. 11·2 *litres weigh* 22 *grams.*

Preparation: Heat ammonium nitrate in a retort. Reaction:

$$NH_4NO_3 = 2\ H_2O + N_2O$$

Experiments:

1. Plunge a lighted taper into a jar of the gas.
2. Burn P in it.
3. Explode a mixture of N_2O and hydrogen.

Properties : A colorless gas with a pleasant smell and sweet taste. Supports combustion, and when inhaled produces transient intoxication and insensibility. Used as an anæsthetic.

Tests : Distinguished from oxygen by its greater solubility. Phosphorus burnt in N_2O takes out oxygen, without lessening the volume.

Nitric Oxide, NO ; molecular weight, 30 ; *density,* 15
11·2 *litres weigh* 15 *grams.*

Preparation : Act upon copper, mercury or zinc with nitric acid. Thus :

$$Cu_3 + 8\ HNO_3 = 3\ Cu\,(NO_3)_2 + 4\ H_2O + 2\ NO.$$

Experiments :

1. Show that it will not support the combustion of a candle, but will that of phosphorus.
2. Mix the gas with air or oxygen.

Properties : Supports combustion of a hot flame ; not soluble to any great extent in water ; is colorless.

Test : Forms a red gas when it escapes into air, or when oxygen is added to it—product N_2O_3 and NO_2 mixed.

Nitrous Anhydride, N_2O_3 ; *molecular weight,* 76 ; *density,* 38. 11·2 *litres weigh* 38 *grams.*

Preparation :

1. Mix 4 volumes of NO with 1 volume O. Thus :
$$4\ NO + O_2 = 2\ N_2O_3.$$
2. Act upon starch, or As_2O_3 with HNO_3.

Properties : A reddish-orange colored gas ; easily condensed into a liquid by a temperature of – 18°C. When passed into ice water it dissolves to a blue liquid and to **Nitrous Acid,** the type of a series of salts called **Nitrites.**

Test : Its color when pure and when dissolved in ice water.

EXERCISE.

1. A dentist wishes to obtain 56 litres of nitrous oxide, how much ammonium nitrate must be used to evolve it?

Ans. 200 grams.

2. Calculate what volume of nitrous oxide can be obtained rom 320 grams of ammonium nitrate. Ans. 89·6 litres.

3. In question (2) calculate the volume in cubic inches.

Ans. 5467·75 cubic inches.

4. How much copper and nitric acid must be used in order to obtain 180 grams of nitric oxide?

Ans. 571·5 and 1512 grams respectively.

5. If a piece of phosphorus be burned in 22 grams of nitrous oxide, what gas and what volume of it will remain?

Ans. 11·2 litres of N.

Nitric Acid : Formula HNO_3 ; *molecular weight,* 63 ; *specific gravity of liquid,* 1·52 ; *boiling point,* 84·5° ; *Freezing,* – 40°.

Sources : Formed in the air by electricity. Exists also in nature in the form of nitrates of potash, soda and lime, which are themselves the product of the decomposition and oxidation of nitrogenous organic compounds with alkalies.

HNO_3 – Hydric Nytrate
HNO_2 – ———— Nitrite

$H_2SO_4 + KClO_3 = HClO_3 + KHSO_4$
for chloric preparation

Preparation :

1. It is prepared for use in the arts from the minerals sodic or potassic nitrate by treating them with sulphuric acid, and distilling ; the reaction being as follows :

$$2\ KNO_3 + H_2SO_4 = HKSO_4 + HNO_3 + KNO_3.$$

The acid distils over. By applying more heat the

$$HKSO_4 + KNO_3 = K_2SO_4 + HNO_3.$$

2. Sodic nitrate may be used instead of potassic nitrate in the above equations.

Experiments :

1. Add HNO_3 to phosphorus.
2. Throw burning charcoal upon fuming HNO_3.
3. Add HNO_3 to carbolic acid.

NOTE. –(These experiments must be performed with care).

Properties : When pure it is colorless ; is easily decomposed ; is a strong oxidizing agent ; and dissolves or attacks nearly all the common metals, forming *salts* with them. Nearly all strong acids act similarly.

Uses : Is used in dyeing, metallurgy, medicine, and in chemical analysis.

Test : It bleaches indigo. With sulphuric acid it imparts a brown, purple or black color to a solution of ferrous sulphate ($FeSO_4$).

EXERCISE.

The principle of atomicity may be employed in forming theoretical salts, by replacing one atom of the hydrogen of an acid with one atom of a monad metal; two atoms of the hydrogen of an acid with one atom of a dyad metal, and so on. For example:

Acid.	*Salt.*	*Name of Salt.*
HNO_3	$AgNO_3$	Silver Nitrate.
H_2SO_4	$ZnSO_4$	Zinc Sulphate.

1. In the same way symbolize the salts which nitric acid may form with the following metals: Potassium, calcium, copper, lead.

2. Name these salts.

3. Symbolize and name the salts which chloric ($HClO_3$) and sulphuric (H_2SO_4) acids may theoretically form with sodium, potassium, magnesium, copper, lead, calcium and iron.

EXERCISE.

1. What weight of nitric acid can be obtained by the decomposition of 505½ grams of nitre by sulphuric acid, and at a moderate temperature? Ans. 315.

2. If 189 grams of nitric acid and 408·3 grams of hydropotassic sulphate are produced in obtaining nitric acid from nitre and sulphuric acid, what quantities of these ingredients must have been used?

Ans. 303·3 grams of nitre; and 294 of acid.

3. What weight of "laughing gas" can be got from 240 grams of ammonic nitrate? What weight of water is produced in the decomposition?

Ans. 132 grams; and 108 grams water.

4. What volume will 132 grams of nitrous oxide occupy?

Ans. 67·2 litres.

5. What volume will 120 grams of nitric oxide occupy?

Ans. 89·6 litres.

6. How much nitric oxide can be obtained from 504 grams of nitric acid by adding it to a sufficient quantity of copper?

Ans. 60.

THE ATMOSPHERE.

11·2 *litres weigh* 14·44 *grams.*

The **atmosphere** is an ocean of mixed gases pressing with a weight of 14·7 lbs. upon every square inch of the earth's surface. That the gases composing it are mixed—not combined chemically—is proved by the following considerations:

1. There is no simple relation in volume or weight between the gases composing it.
2. On mixing its constituent gases in proper proportions, no visible or thermotic changes occur.
3. The air dissolved in water does not contain oxygen and nitrogen in the same proportions as they are found in the atmosphere. 01:181
4. Nitric oxide passed into free oxygen or air forms red fumes—never when passed into compounds of oxygen and nitrogen.

The average composition of air is about as follows:

Oxygen, including Ozone	206·1	cub. centimetres
Nitrogen	779·5	
Aqueous vapor	14·	
Carbon dioxide	·4	
Traces of ammonia, nitric acid and sulphuretted hydrogen.		
Total	1000·	

In large towns, sulphurous anhydride and sulphuretted hydrogen are present in air in small quantities. Minute particles of solid organic matter are also found floating through it, such as spores and fungi, and the supposed germs of disease.

The source of carbon dioxide in the air is respiration, combustion and decay, &c. It supplies carbon to plants.

The source of ammonia is the decay of organic matter. It furnishes nitrogen to the soil, and thence to plants and animals.

Carbon: Symbol, C; atomic weight, 12; *specific gravity, as diamond, about* 3·4.

Sources: Occurs in three allotropic forms:

1. **Crystalline,** as diamond.
2. **Graphitic,** as graphite, plumbago or black-lead; and
3. **Amorphous,** as charcoal and coke.

It is the characteristic element in all *organic* compounds. **Diamond** is pure carbon crystallized, and may be burned in the arc of the voltaic battery—product, carbonic anhydride. **Plumbago** is found as a mineral; used for making drawing pencils, for stove polish, and for making crucibles when mixed with clay.

There are many varieties of the amorphous form of carbon. The following are the principal ones:

Allotropic forms are forms which have many of their physical and and some of their chemical properties ~~the same~~ different but which nevertheless consist of nothing but the single element

[illegible] Dissertation

(a) **Pit Coal,** composed of carbon in large proportion, oxygen in smaller quantity, hydrogen in smaller, nitrogen in still less, and, a variable proportion of saline and earthy matter ; has been formed by the submersion of huge forests under the sea, long ages ago, the wood being slowly changed into coal by the combined action of the pressure of water upon it, and of moderate heat from the interior of the earth.

(b) **Anthracite** coal contains about 90 per cent. of carbon. When **bituminous** coal is heated in closed iron cylinders free from air, a large quantity of *gas* and *tar* is formed, containing the oxygen, hydrogen, nitrogen, and some of the carbon of the coal ; the residue is called **coke.** This is how coal gas is manufactured. This process of destructive distillation may be applied to wood also, when an inflammable *gaseous* product will be given off ; **wood-tar, vinegar** and **wood-naptha,** are the liquid products ; the black porous mass left behind is called *charcoal.*

(c) **Lamp-black,** the basis of printer's ink, is another form of carbon.

(d) **Animal charcoal** or *ivory black* is made by heating the bones and flesh of animals in iron retorts, and is used in refining sugar, and as a decolorizing agent.

Uses : Its chief use is, of course, for fuel. Charcoal is a good *disinfectant* and *antiseptic*, on account of its absorbent and purifying power. Its purifying power is due to the action of the oxygen condensed from the surrounding air within the pores of the charcoal. Charcoal is used for making water filters, and is also the great *reducing agent* of the metallurgist.

COMPOUNDS OF CARBON AND OXYGEN.

Carbon Monoxide (Carbonic Oxide): Formula, CO ; *molecular weight,* 28 ; *density,* 14. 11·2 *litres weigh* 14 *grams.*

Sources : This gas is formed by ordinary combustion in our coal stoves, and causes the "*blue blazes*" that are seen flickering over the top of coal fires.

Preparation :

1. By passing carbon dioxide over red hot charcoal.

$$CO_2 + C = 2\,CO.$$

2. By heating oxalic acid and sulphuric acid in a retort. The latter takes from oxalic acid the elements of water, and the residue breaks up, forming a mixture of the two gases—carbon dioxide and carbonic oxide. Thus :

$$C_2H_2O_4 + H_2SO_4 = H_2O.\ H_2SO_4 + CO_2 + CO.$$

The carbon dioxide is absorbed on passing the mixed gases through a solution of caustic potash.

Properties : It is a colorless, tasteless gas, and violently poisonous when breathed. It burns with a pale blue flame, taking up oxygen and forming carbon dioxide.

Preparation of CO_2 by treating marble
ith Sulphuric acid —:
$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2$

Experiments :

1. Burn a jet of the gas.
2. Pass the gas through benzine and then burn it

Tests : The color of its flame. The product (CO_2) of the combustion of this gas turns lime water a milky color. The gas itself does not affect lime water.

Carbonic Anhydride (*Carbon dioxide, carbonic acid gas, choke damp*) : *Symbol*, CO_2 ; *atomic weight*, 44 ; *density*, 22. 11·2 *litres weigh* 22 *grams*.

Sources : In respiration, this gas is given off abundantly ; the air which has been breathed once contains from 3 to 4 per cent. of it. Fermentation, putrefaction, decay, and germination, as well as all ordinary combustion, give rise to it. It accumulates in old pits, wells, and mines, and issues sometimes from fissures in the earth and from the craters of volcanoes. It exists very abundantly in combination with lime and magnesia.

Preparation :

1. Is usually made by treating chalk or marble with hydrochloric acid, the decomposition being :

$$CaCO_3 + 2\ HCl = CaCl_2 + H_2O + CO_2.$$

2. By pouring a strong acid upon any carbonate, *e.g.*, K_2CO_3, Na_2CO_3, &c.

Experiments:

1. Place a lighted taper in a jar of the gas.
2. Pour the gas from one jar to another.
3. Pass the gas through lime water.
4. Pass air from the lungs through lime water.
5. Absorb some of the gas with caustic potash.

Properties: Carbonic anhydride is a heavy transparent gas without colour. It may be condensed to a liquid by applying cold and a pressure of 40 atmospheres, or it may be generated as a liquid in strong iron tubes; it may even be frozen to a snow-white solid, which, when mixed with ether, produces a freezing mixture of – 75°. When heated it accumulates in the upper part of the room, and therefore, in ventilating a room, openings should be made for its escape, near the ceiling, whilst fresh air should be admitted near the floor. Its vitiating effects upon the atmosphere are only prevented by the action of plants upon it, which, in presence of sunlight, decompose it, retain the carbon and give out the oxygen. It does not support combustion.

Test: The test for this gas is lime water, which it renders turbid, owing to the formation of *chalk.* It does not burn, cannot be breathed pure, but mixed (from 3 to 4 per cent.) with air, it acts as a narcotic poison, and produces death.

$4K_2 + 3CO_2 = 4K_2O + 3$

EXERCISE.

1. How much potassium will be required to decompose 110 grams of carbon dioxide? ANS. 391 grams.

2. If 10 litres of carbon dioxide be passed over red hot charcoal, what gas, and how many litres of it, will be formed? What weight of it? ANS. 20 litres; 25 grams of CO.

3. 20 litres of carbonic oxide are burned in oxygen gas. What gas is produced, and what volume and weight of it?
ANS. 20 litres; 39·2 grams of CO_2.

4. How much carbon can be obtained from 264 grams of carbon dioxide? ANS. 72 grams.

5. What volume of oxygen is required to burn 66 grams of carbon? ANS. 123·2 litres.

6. In question (5) what volume of air would be needed for the combustion? ANS. 616 litres.

7. What volume do 110 grams of carbon dioxide occupy?
ANS. 56 litres.

8. What volume do 140 grams of carbonic oxide occupy?
ANS. 112 litres.

9. What weight of carbon dioxide can be obtained from 250 grains of pure limestone by treating with hydric chloride?
ANS. 110 grains.

10. What weights of carbonate of lime and hydric chloride must be decomposed to produce 352 grams of carbon dioxide?
ANS. 800; 584 grams.

11. What volume will 98 grams of carbonic oxide occupy?
ANS. 78·4 litres.

12. If 270 grams of oxalic acid be decomposed by sulphuric acid, find the volume and weights of the gases produced.
ANS. 132 grams; 67·2 litres of CO_2. ANS. 84 grams; 67·2 litres of CO.

13. What volume of carbon dioxide will be produced by the combustion of 24 grams of carbon in oxygen gas.

ANS. 44·8 litres.

14. Calculate the weight and volume of carbon dioxide produced by the combustion of 42 grams of carbonic oxide?

ANS. 66 grams ; 33·6 litres.

COMPOUNDS OF CARBON AND HYDROGEN: HYDROCARBONS.

These are very numerous, and their full consideration belongs to organic chemistry. The simpler ones exist as gases, the more complex, as liquids, and the most complex in composition, as solids. All are inflammable. Only three will be noticed here: Marsh gas, Acetylene, and Ethylene.

Marsh Gas (Light carburetted hydrogen, "Fire-damp"), CH_4; *molecular weight*, 16; *density*, 8.
11·2 *litres weigh* 8 *grams.*

Sources: This substance is generated in marshes by the decomposition of vegetable matter containing carbon and hydrogen. Formed in coal mines also, and on being mixed with air and ignited, causes fearful explosions—product CO_2 and H_2O. To prevent these, Sir H. Davy invented his **Safety Lamp**.

Preparation: Strongly heat one part sodic acetate, and four parts sodic hydrate, and quick lime. Reaction:—

$$NaC_2H_3O_2 + NaHO = NA_2CO_3 + CH_4.$$

The quick lime probably acts by **catalysis**.

Properties : Colourless, invisible, odorless gas; scarcely soluble in H_2O ; does not support combustion or respiration; burns with a pale, almost non-luminous, flame.

Experiments :

1. Burn a jar full of the gas.

2. Explode a mixture of 1 vol. of CH_4 and 2 vols. of O.

Its combustion : $CH_4 + 2\,O_2 = CO_2 + 2\,H_2O$. Remembering that every molecule occupies two volumes, this equation may be translated thus: Two vols. of CH_4 burnt with four vols. of O yields two vols. CO_2, and four vols. of vapor of H_2O. Assuming that O constitutes $\frac{1}{5}$ of the air, it will require 10 vols. of air to furnish oxygen enough to burn one volume of CH_4.

Tests : Pale flame, and deposition of black soot upon porcelain held in its flame. This latter distinguishes it from H. When passed through a tube containing intensely hot pumice stone, one vol. of it breaks up into two vols. of H, and C is deposited on the stone.

EXERCISE.

1. Calculate what quantities of sodic acetate and sodic hydrate must be decomposed to yield 134·4 litres of marsh gas. ANS. 492 and 240 grams respectively.

2. If 10 litres of marsh gas be passed through a tube containing intensely heated pumice stone, what gas and what volume of it will be eliminated?

ANS. 20 litres of H.

3. If 15 litres of marsh gas be mixed with an equal volume of oxygen, and if the mixture be exploded at ordinary temperatures, what gas, and what volume of it will remain ; and what gas, and what volume of it will be produced ?

Ans. 7·5 litres of CH_4 ; and 7·5 litres of CO_2.

4. What volume will 48 grams of marsh gas occupy ?

Ans. 67·2 litres.

5. 70 litres of marsh gas are burnt in air, what weight and volume of carbon dioxide will be produced ?

Ans. 70 litres, or 137·5 grams.

Acetylene, C_2H_2; *molecular weight* 26 ; *density* 13, 11·2 *litres weigh* 13 *grams.*

Preparation :

1. Is formed by the direct union of carbon and hydrogen at a very high temperature.
2. By the incomplete combustion of many organic substances, as coal gas, &c.

Properties : Colorless gas, burns with a bright luminous flame, has a peculiar disagreeable smell, noticeable when a candle burns with a smoky flame ; poisonous ; forms explosive compounds with some metals, as potassium.

Tests : Pass the gas through an ammoniacal solution of a cuprous salt, and a dark blood-red precipitate will be formed.

Ethylene (Ethene. Olefiant gas. Heavy carburetted hydrogen), C_2H_4; *molecular weight*, 28 ; *density*, 14. 11·2 *litres weigh* 14 *grams.*

It is called *olefiant*, because it unites with chlorine

as to form a heavy oily liquid, called "Dutch iquid."

reparation :

1. By heating coal in a closed vessel. When obtained in this way, the gas is mixed with many others.
2. By heating alcohol mixed with double its volume of sulphuric acid :

$$C_2H_6O + H_2SO_4 = H_2O,\ H_2SO_4 + C_2H_4.$$

xperiments :

1. Burn a jar full of the gas.
2. Mix equal volumes of the gas and chlorine.
3. Explode 1 vol. of C_2H_4 and 3 vols. of O.

roperties : Colorless, slightly sweetish taste, scarcely soluble in H_2O, does not support combustion or respiration, burns with a dense bright flame. Its combustion in oxygen may be thus represented :

$$C_2H_4 + 3\ O_2 = 2\ CO_2\ + 2\ H_2O$$

From this it will be seen that one vol. of C_2H_4 requires for its combustion three vols. of O, or 15 vols. of air.

ests : Its faint smell ; its luminous flame ; its forming "Dutch Liquid."

EXERCISE.

1. I desire to obtain 33·6 litres of ethylene, how much pure lcohol must I use? Ans. 60 grams.

2. How much oxygen is required for the perfect combustion of 10 litres of olefiant gas: and what weight and volume of gas is produced at ordinary temperatures?

Ans. 30 litres of O; 20 litres or 39·2 grams of CO_2.

3. How many volumes of hydrogen can be obtained from 18 litres of olefiant gas? Ans. 36 litres.

4. Calculate what volume 126 grams of ethylene will occupy. Ans. 100·8 litres.

5. What weight and volume of carbon dioxide and steam will be produced by burning 50 litres of olefiant gas in oxygen? Ans. 100 litres or 196·4 grams of carbon dioxide. Ans. 100 litres or 80·3 grams of steam reduced to 0°C and 760 m.m.

6. On burning a quantity of olefiant gas in air, it was observed that 88 grams of carbon dioxide were produced, what volume of ethene was consumed? Ans. 22·4 litres.

COMPOUND OF CARBON & NITROGEN.

Cyanogen, CN (or Cy), molecular weight 26; *density,* 13. 11·2 *litres weigh* 13 *grams.*

This compound is a good example of a monad radicles.

Preparation:

By heating a metallic cyanide, as mercuric cyanide.

$$Hg(CN)_2 + \text{heat} = Hg + C_2N_2.$$

Properties: A gas, poisonous, colorless, and having the odor of peach blossoms, burns with a purple-mantled flame; combines with metals to form cyanides; water dissolves four volumes of it.

Test: Its peculiar smell, and rose-colored flame.

COAL GAS.

Coal gas is a mixture of several gases, its average composition being somewhat as follows :

Hydrogen	45·
Marsh gas	35·
Carbonic oxide	7·
Olefiant gas	4·
Butylene	2·4
Hydric sulphide	·3
Nitrogen	2·5
Carbon dioxide	3·8
Total	100· vols.

Formed by distilling coal in large iron retorts, the products being (*a*) coal gas, (*b* coal tar, and ammoniacal liquor, and (*c*) crude coke. From coal tar are obtained, *aniline, creosote, benzole, napthaline, &c.*

The impurities of coal gas are chiefly sulphuretted hydrogen, carbon dioxide, ammonia, and carbon disulphide. The two former may be partially removed by passing the gas through vessels containing slaked lime. The ammonia is easily separated, but the carbon disulphide cannot be removed by any practicable means.

COMBUSTION.

The term combustion in its widest signification means the union of an element, or of an element with a compound, or of a compound with a compound—the union being always attended with the production of *heat*, and frequently of *light*.

Ordinary combustion means the union of the oxygen of the air with the elements of wood or coal in stoves, or its union with the elements of coal oil in our lamps, or tallow in our candles.

Extraordinary combustion may be defined as meaning all other cases of chemical union.

If union goes on very rapidly, great heat is evolved as in the case of the explosion of gunpowder, or of a mixture of hydrogen and oxygen gas. But the union may go on very slowly, as in the rusting of iron, and then, though, a fixed amount of heat is always evolved for a given weight of the uniting substances, yet, the process of union being spread over a comparatively great length of time, the heat generated never becomes so apparent as when union is instantaneous.

Heat is, therefore, intensified in two ways:

1. By shortening the time in which a given weight of matter is consumed.

2. By diminishing the space.

STRUCTURE OF FLAME.

The flame of a common candle may be considered as the type of all other flames. It consists of three cones—the two outer ones enveloping the central one:

1. The central cone, called the cone of **non-combustion**, is dark in color, and consists of unburnt gases.

2. The cone surrounding the first one, and called the cone of **partial combustion**, is yellow in color, and consists of burning gases—chiefly oxygen uniting

with hydrogen and hydro-carbons. It has incandescent particles of carbon floating upwards through it. This cone is the *light-giving* portion of the flame, and forms the largest part of the flame of the candle, coal oil lamp, or gas jet.

3. The cone of **complete combustion** is the outer one. It is of a blue color, and, as the oxygen of the air has free access to this part of the flame, the union of the oxygen, carbon and hydrogen is complete, and a high temperature is the result. This cone is chiefly the *heat-giving* portion of the flame. It constitutes the largest part of the flame of a Bunsen's burner, or of a spirit lamp.

Experiments with the cone of non-combustion :

1. Convey the gases in a small glass tube to a distance from the flame, and burn them.
2. Press a piece of wire gauze down upon the flame, and note its appearance when viewed from above.

Experiments relating to the light-giving part of flame :

1. Hold a piece of procelain over a candle flame. It becomes covered with soot or finely divided carbon.
2. Supply finely divided particles of iron or charcoal to the flame of a spirit lamp. The heat-giving part of the flame becomes quite luminous.
3. Show a Bunsen's lamp burning, first with its air holes closed, and then with them open.

4. Hold a spiral piece of platinum wire in the flame of a Bunsen's lamp. The flame then gives much light.
5. Exhibit the Drummond light, and the oxy-hydrogen lime light.
6. Burn a piece of magnesium wire.

These experiments prove that the light of a flame is caused by the incandescent particles of some solid substance contained in the flame itself, or affected by it.

When too much oxygen or air is supplied to a flame giving a uniform light, the effect is to diminish its lighting power, by causing a more perfect combustion of the particles of carbon. If a flame is smoky, it is evident that carbon is greatly in excess, and that more oxygen is required for its combustion. In practice, the supply of air or oxygen to our lamps is increased by using a chimney.

HALOGENS.

This is the name given to four elements, *Chlorine*, *Bromine*, *Iodine* and *Flourine*, all having relations to each other that mark them off as members of the same group or family of elements.

CHLORINE.

Chlorine : Symbol, *Cl* ; *atomic weight*, 35·5 ; *molecular weight*, Cl_2, 71 ; *density*, 35·5. 11·2 *litres weigh* 35·5 *grams.*

Sources : Is never found uncombined, and, generally

obtained from the abundant and well known compound sodic chloride, or common salt.

Preparation:

1. Gently heat a mixture of manganese dioxide, sulphuric acid and salt in a glass retort. The reaction is thus represented:

$$MnO_2 + 2\ NaCl + 3\ H_2SO_4 = MnSO_4 + 2\ NaHSO_4 + 2\ H_2O + Cl_2.$$

2. $MnO_2 + 4\ HCl = 2\ H_2O + MnCl_2 + Cl_2.$

Experiments:

1. Pass chlorine into water colored with indigo, or litmus.
2. Bleach moistened calico.
3. Explode a mixture of equal volumes of hydrogen and chlorine by sunlight.
3. Pour some powdered antimony, or bismuth, into a jar of the gas.

Properties: Is a greenish yellow gas, with a suffocating smell; cannot be collected over water or mercury, as it dissolves in the former, and combines with the latter; it decomposes water giving off oxygen. Copper leaf, powdered bismuth, powdered antimony, and many other metals will burn brilliantly in chlorine gas, forming chlorides. It is a splendid disinfectant, and bleaches animal and vegetable colors by removing hydrogen from water, the liberated oxygen helping to destroy the coloring matter.

Tests: Its characteristic color and smell, and its spontaneous union with phosphorus and hydrogen.

EXERCISE.

1. How much chlorine by weight and volume can be obtained from 1460 grams of hydric chloride?
ANS. 710 grams; 224 litres.

2. How much chlorine can be liberated from 585 grams of common salt? What volume will it occupy?
ANS. 355 grams; 112 litres.

3. What volume will 284 grams of it occupy?
ANS. 89·6 litres.

4. What quantities of manganous sulphate, hydro-sodic sulphate, water, and chlorine, will be formed by the decomposition of 351 grams of common salt, with manganese dioxide and sulphuric acid?
ANS. 453, 720, 108, 213 grams respectively.

5. If 142 grams of chlorine gas be passed into steam, what substances will be formed, and what weight and volume of each? ANS. 146 grams, or 89 6 litres of hydric chloride; and 32 grams, or 22·4 litres of oxygen.

6. What weight of hydric chloride will 261 grams of manganese dioxide require for its decomposition?
ANS. 438 grams.

COMPOUNDS OF CHLORINE.

Hydrochloric Acid ("Spirit of salt"): Formula, HCl*; molecular weight,* 36·5*; density,* 18·25. 11·2 *litres weigh* $18\frac{1}{4}$ *grams.*

It is frequently called muriatic acid. The commercial acid is usually of a yellowish color, and consists of water thoroughly impregnated with the acid gas.

Forms chlorides with metals or their oxides. Its salts are termed *haloid salts.*

Preparation :

1. Equal volumes of H and Cl in direct sunlight unite with a powerful explosion forming this acid. Thus :

$$H_2 + Cl_2 = 2\ HCl.$$

2. Generally prepared by heating a mixture of common salt and "oil of vitriol :"

$$NaCl + H_2SO_4 = NaHSO_4 + HCl.$$

Experiments :

1. Pass the gas into H_2O coloured with litmus.
2. Bring the gas into contact with liquor ammoniæ. Explain the cause of the white fumes that are produced.
3. Show that it cannot be collected over water.

Properties : It is a transparent and colorless gas, with a pungent smell and intensely acid taste ; is not inflammable ; is soluble in water to the extent of 480 times its own volume, producing a powerfully acid solution ; may be liquefied ; forms copious white fumes as it escapes into air.

Tests : Its irritating smell, its incombustibility, its solubility in water. It forms a white precipitate with nitrate of silver.

EXERCISE.

The principle of atomicity may be employed in forming the chlorides of the metals, by taking one molecule of hydric chloride as a type, and substituting for its atom of hydrogen a monad metal. One atom of a dyad metal must be substituted for two atoms of hydrogen in two molecules of hydric chloride to form the chloride of a dyad metal, and so on with triads, tetrads, &c. There are important exceptions to this application of the principle.

Type.	*Chloride.*	*Name.*
HCl	$NaCl$	Sodic chloride
$2\ HCl$	$CaCl_2$	Calcic chloride.

1. Apyly this principle and form the chlorides of the following metals :

Arsenic, gold, tin, manganese, iron, potassium, mercury, silver, zinc, calcium.

2. Name the compounds thus formed.

Note.—The compounds which chlorine forms with metals are often termed haloid salts, on account of their resemblance to other chemical salts.

EXERCISE.

1. If 8 litres of hydrogen be mixed with 11 of chlorine, and the mixture be placed in sunlight, what substance will be formed, and what volume of it in the gaseous condition?
Ans. 16 vols. of HCl ; 3 vols. of Cl will remain.

2. What weight of common salt and sulphuric acid must be taken if it be required to eliminate 146 grams of hydric chloride? Ans. 234 grams of $NaCl$; 392 of H_2SO_4.

3. Calculate the amount of hydro-sodic sulphate that will be produced in generating 219 grams of hydric chloride from salt and sulphuric acid at a moderate temperature?
Ans 720 grams.

4. How many volumes of chlorine can be obtained from 20 litres of hydro-chloric acid gas? Ans. 10 litres.

5. What volume will 73 grams of hydric chloride occupy at the standard temperature and pressure?

Ans. 44·8 litres.

6. What is the percentage composition of the gas?

Ans. 2·74 of H, and 97·26 of Cl.

7. Calculate the weight and volume of hydric chloride that can be formed by heating to a moderate temperature 409·5 grams of common salt and 686 grams of sulphuric acid?

Ans. 255·5 grams or 156·8 litres.

CHLORINE AND OXYGEN.

Oxygen forms with chlorine three well known oxides, and two hypothetical ones.

Formula.	Name.	Corresponding Acid.
Cl_2O.	Hypochlorous anhydride.	$HClO$ Hypochlorous acid.
Cl_2O_3.	Chlorous anydride.	$HClO_2$ Chlorous acid.
Cl_2O_4.	Chloric peroxide.	No corresponding acid.
Cl_2O_5.	Not eliminated.	$HClO_3$ Chloric acid.
Cl_2O_7.	Not eliminated.	$HClO_4$ Perchloric acid.

All the compounds of oxygen and chlorine are unstable, and most of them are explosive.

Bleaching Powder is a mixture of calcic chloride and hypochlorite of lime. It is commonly called "chloride of lime," and is formed by passing chlorine gas into a chamber containing slaked lime spread on large trays.

$$2\ Ca(HO)_2 + 2\ Cl_2 = CaCl_2 + Ca(ClO)_2 + H_2O.$$

Bleaching powder, as its name indicates, is used for bleaching purposes. A solution of the powder in water is filtered, and any article which it is desirable to bleach is soaked in the solution, and then in a *very* dilute solution of sulphuric acid. Chlorine is at once liberated, and uniting with the hydrogen of water liberates the oxygen which destroys the coloring matter.

Chloric acid, $HClO_3$, is not of itself an important compound, but its salts are important, especially the one known as potassic chlorate.

Potassic chlorate, $KClO_3$, is prepared by passing chlorine gas into a hot solution of caustic potash. The process of forming it may be symbolized as follows:

$$6\ KHO + 3\ Cl_2 = 5\ KCl + 3\ H_2O + KClO_3.$$

Chlorate of potash is a white crystalline solid, and is sparingly soluble in water. It is used extensively in the manufacture of fireworks and lucifer matches, and is the salt from which oxygen gas is most conveniently obtained.

SULPHUR.

Sulphur: Symbol, S; atomic weight, 32; *melting point,* 115°; *boiling point,* 446°.

Sources: Old name, "brimstone;" found free in volcanic countries; also combined with metals, as sulphides, for example, galena, blende, iron pyrites.

Preparation :

1. *Roll* sulphur is obtained by pouring melted sulphur into wooden moulds of a cylindrical form.

2. The *flowers* of sulphur is produced by condensing sulphur vapor upon the walls and floor of a large cool room, into which the vapor is passed from a large furnace in which the ore is roasted.

Properties : Is yellow, brittle, solid, insoluble in water, but very inflammable, burning with a blue flame; is **dimorphous,** that is, crystallizes in two different forms; generally purified from earthy matters by distillation.

Uses : Sulphur is used in making matches and gunpowder. It forms two compounds with oxygen, viz.: sulphurous anhydride, SO_2, and sulphuric anhydride, SO_3, both of which, when united with water, form acids.

COMPOUNDS OF SULPHUR.

Sulphurous Anhydride (Sulphur dioxide) : Formula, SO_2 *; molecular weight,* 64 *; density,* 32.

Preparation :

1. This substance is produced whenever sulphur is burned in air, or in oxygen gas.

2. Sulphur dioxide is usually obtained as follows:

$$2\ H_2SO_4 + Cu = CuSO_4 + 2\ H_2O + SO_2.$$

It is used for bleaching articles that would be ruined if Cl were used. Chlorine destroys the coloring matter, SO_2 does not. The latter bleaches by removing oxygen.

Experiments:

1. Place a lighted taper in the gas. It is extinguished.
2. Pass the gas into an infusion of litmus.
3. Pour the gas downwards upon a lighted taper placed in the bottom of a jar.
4. Show its solubility in H_2O, and the subsequent acidity of the water.

Properties: It is colorless, transparent, not inflammable, and has a pungent, suffocating odor. It forms, with water, sulphurous acid. Thus:

$$SO_2 + H_2O = H_2SO_3.$$

Tests: Its weight, smell, acid properties when united with water, and its bleaching properties.

Sulphuric Acid: Formula, H_2SO_4; *molecular weight,* 98; *specific gravity of liquid,* 1·846.

This is the most important of all the acids, and the most extensively used in our manufactures.

Preparation:

1. *Nordhausen Sulphuric Acid* is made by the distillation of dried sulphate of iron (green vitriol).

2. The great bulk of the acid of commerce is manufactured as follows :

Sulphurous anhydride, steam, air, and nitric oxide, are passed into an immense chamber. "The nitric oxide in presence of oxygen immediately becomes nitrogen peroxide, and this, when mixed with sulphurous anhydride and a large quantity of water, furnishes sulphuric acid and nitric oxide. The sulphuric acid remains dissolved in the water, while the nitric oxide, by absorbing oxygen from the air, again becomes nitrogen peroxide ; this combines with fresh sulphurous anhydride, which, when acted on by water, becomes sulphuric acid, the nitric oxide being again liberated, to go through the same series of changes with fresh portions of oxygen and sulphurous anhydride as long as any remain in presence of each other uncombined :

$$NO_2 + SO_2 + xH_2O = NO + (x-1)\,H_2O + H_2SO_4."$$

This acid gives rise to a large class of salts called sulphates. If one atom of hydrogen, in the molecule of H_2SO_4, be replaced by one atom of a monad metal, there is formed what is called an **Acid sulphate** ; if all the hydrogen be replaced by a metal, a **Normal** or **Neutral sulphate**.

Properties: The oil of vitriol of commerce is a dense oily-looking colorless liquid, without odor, is intensely caustic, and chars almost all organic substances, "owing to its powerful attraction for moisture."

Test: Baric chloride gives with sulphuric acid, or any soluble sulphate, a white precipitate insoluble in all acids. Sulphuric acid chars organic compounds.

Hydric Sulphide (Sulphuretted hydrogen): Formula, H_2S*; molecular weight,* 34*; density,* 17.
11·2 *litres weigh* 17 *grams.*

Sources: Is found free in volcanic countries, and also dissolved in spring water. Also called Hydrosulphuric acid.

Preparation:

1. Ferrous sulphide treated with dilute sulphuric acid. Thus:

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

2. By treating antimony sulphide with hydrochloric acid:

$$Sb_2S_3 + 6\ HCl = 2\ SbCl_3 + 3\ H_2S.$$

Experiments:

1. A jet of the gas burns with a blue flame.
2. Explode a mixture of 2 vols. of H_2S with 3 vols. of O.
3. Pass a stream of the gas into solutions of cupric sulphate, ferrous sulphate, zinc sulphate, and acetate of lead, and observe the effects.

roperties : Is a colorless, transparent and poisonous gas, with the odor of rotten eggs. Soluble in water to about the extent of 4½ times its own volume; and burns with a blue flame. It has an acid reaction.

est : It blackens acetate of lead paper. This, with its smell, distinguishes it from all other gases.

EXERCISE.

1. Calculate the percentage composition of sulphur dioxide.
Ans. 50 of O and 50 of S.

2. What volume will 112 grams of sulphur dioxide occupy?
Ans. 39·2 litres.

3. Find the weight and volume of sulphur dioxide that can be obtained from 588 grams of sulphuric acid and 10 lbs. of copper.
Ans. 192 grams; 67·2 litres.

4. If sulphur trioxide be passed through a tube heated to a high temperature it breaks up into sulphur dioxide and oxygen gas. Find how much oxygen can be obtained in this way from 320 grams of sulphur trioxide.
Ans. 48 grams; 33·6 litres.

5. How many litres of sulphur dioxide must be dissolved in water to produce 410 grams of sulphurous acid.
Ans. 10 litres.

6. If 48 grams of sulphur be completely oxidized in presence of vapor of water, what compound, and what weight of it, will be produced?
Ans. 147 grams of H_2SO_4.

7. Every volume of sulphuretted hydrogen requires for its combustion one and a half volumes of oxygen; what compound and what weight of it will be formed by the combustion of 78·4 litres of this gas?
Ans. 287 grams of H_2SO_3.

8. How much sulphide of iron and sulphuric acid must be used to evolve 89·6 litres of sulphuretted hydrogen?

ANS. 352 grams; 392 grams respectively.

COMPOUND OF CARBON AND SULPHUR.

Carbon disulphide (Carbonic sulphide, sulphocarbonic acid): Formula, CS_2; *molecular weight,* 76; *density of vapor,* 38.

Preparation: This substance is formed by passing sulphur vapor over red hot charcoal and condensing the product. The chemical equation is:

$$2\ S_2 + C_2 = 2\ CS\ .$$

Experiments:

1. Dissolve a piece of P in CS_2. Then dip a piece of paper in the solution, and allow it to dry upon an iron frame. Spontaneous combustion takes place.

2. Ignite a few drops of the liquid.

Properties: It is a very volatile liquid with a disagreeable smell; it is heavy, transparent, and colorless; does not mix with water; it boils at 43°C, and when its vapor is mixed with oxygen, the mixture becomes explosive. Its combustion in air produces carbon dioxide, and sulphur dioxide. It readily dissolves resins, phosphorus, iodine, sulphur, and india-rubber.

Uses: It is used extensively in the arts, especially in the vulcanization of caoutchouc, and in the manufacture of gutta-percha.

PHOSPHORUS.

Phosphorus: Symbol, P; atomic weight, 31; *molecular weight,* 124; *density in gaseous state,* 62.

Sources: Phosphorus is never found uncombined in nature. By far the greater part of the bones of animals is made up of phosphate of lime. Indeed calcined bones were for many years the chief source of this element. At present it is largely obtained from mineral phosphates.

Preparation: Treat bone-earth or the mineral phosphate of lime with dilute sulphuric acid, and there will be formed an insoluble calcic sulphate and superphosphate of lime. Thus:

$$Ca_3(PO_4)_2 + 2\ H_2SO_4 = 2\ CaSO_4 + CaH_4(PO_4)_2$$

Filter the product, and throw away the insoluble sulphate. Then evaporate the solution to dryness, mix the residue with charcoal, and distil in an earthen retort. Carbonic oxide will be formed; and phosphorus vapor will pass over, and may be condensed under water. This reaction may be thus represented:

$$3\ CaH_4(PO_4)_2 + C_{10} = Ca_3(PO_4)_2 + 6\ H_2O + 10\ CO + P_4.$$

Phosphorus exists in two well-known forms:

1. As **yellow** phosphorus.
2. As **red** or **amorphous** phosphorus.

The yellow variety is obtained as outlined above, but requires some further purification. The red is formed by heating yellow phosphorus, in an atmosphere from which oxygen is excluded, to a temperature of about 240°C.

Properties: The properties of the two varieties of this element may be contrasted as follows:

YELLOW.	RED.
Poisonous.	Innocuous.
Strong odor.	Nearly odorless.
Phosphorescent.	Not phosphorescent.
Melts at 44°C.	Melts above 260°C.
Transparent.	Opaque.
Soluble in various liquids.	Almost insoluble.
Soft.	Hard as brick.
Crystalline.	Amorphous.
Must be kept under water.	Remains unchanged in air.

Uses: This element is extensively used in the manufacture of lucifer-matches. A paste is made of phosphorus, potassic chlorate, glue, and powdered sand, and the ends of the matches are tipped with it. The "safety" match is tipped with a paste of potassic chlorate and antimonious sulphide, and the "rubber," upon which it has to be rubbed before it ignites, is made of red phosphorus and antimonious sulphide.

The ordinary match, as well as the "safety" one

ignites by friction. The rubbing generates sufficient heat to cause the phosphorus to take fire, and when once ignited the combustion is supported by the oxygen supplied by the potassic chlorate.

EXERCISE.

1. What weight of phosphorus can be obtained from 1053 grams of superphosphate of lime? Ans. 186 grams.

2. How much sulphuric acid will be required for the decomposition of 62 grams of calcic phosphate? How much superphosphate of lime will be produced in the process?
Ans. 39·2; and 46·8 grams.

3. In question (2) calculate what weight of phosphorus would be produced, and what volume it would occupy, if it could exist in the gaseous condition at the standard temperature and pressure.
Ans. 8·26 grams; 1·5 litres nearly.

COMPOUNDS OF PHOSPHORUS.

Phosphorus and oxygen form two well-known compounds:

Name.	Formula.	Corresponding Acids.
Phosphorus trioxide.	P_2O_3.	H_3PO_3 Phosphorous acid.
Phosphorus pentoxide.	P_2O_5.	H_3PO_4 Orthophosphoric acid. HPO_3 Metaphosphoric acid. $H_4P_2O_7$ Pyrophosphoric acid.

Phosphorus trioxide, or phosphorus oxide, is formed by burning phosphorus in a limited supply of air. Obtained in this way it presents the appearance of a white powder.

Phosphorus Pentoxide, or phosphoric oxide, is produced as white fumes under a bell jar when phosphorus is burned in a copious supply of dry air, or oxygen gas. These fumes soon settle as a snow white powder, which, when exposed to the air for a few minutes, deliquesces to a liquid. It has an intense affinity for water, with which it unites to form, in the first place, probably, **metaphosphoric acid**, HPO_3. Thus:

$$P_2O_5 + H_2O = 2\ HPO_3.$$

If the solution represented by the formula HPO_3 be boiled in water for some time, orthophosphoric acid is formed. Metaphosphoric acid is often called "glacial phosphoric acid."

Orthophosphoric acid, H_3PO_4.

This substance can be prepared by carefully heating small pieces of phosphorus in dilute nitric acid. The nitric acid oxidizes the phosphorus, and glacial phosphoric acid is formed. This, as stated above, when heated with water takes up another molecule of water and forms orthophosphoric acid. This substance, H_3PO_4, is interesting as illustrating what is called a **tri-basic** acid; that is, an acid which is capable of forming three kinds of salts, according as one, two or three of its hydrogen atoms are replaced by one, two, or three atoms of a monad metal. For example:

NaH_2PO_4 is called dihydro sodic phosphate.

Na_2HPO_4 is called hydro disodic phosphate.

Na_3PO_4 is called trisodic phosphate.

The **basicity** of an acid, therefore, depends upon the number of exchangeable atoms of hydrogen which its molecule contains. Nitric acid, HNO_3, is **mono-basic**; sulphuric acid is **bi-basic**.

COMPOUND OF PHOSPHORUS AND HYDROGEN.

Phosphoretted hydrogen (Phosphine): Formula, PH_3; molecular weight, 34; *density,* 17. 11·2 *litres weigh* 17 *grams.*

Preparation:

1. Heat phosphorus acid in a small retort:

$$4\ H_3PO_3 = 3\ H_3PO_4 + PH_3.$$

2. Boil some small pieces of phosphorus in a solution of sodic hydrate, or of slaked lime.

Reaction:

$$P_4 + 3\ H_2O + 3\ KHO = 3\ KH_2PO_2 + PH_3.$$

Experiments:

1. Carefully allow bubbles of the gas to escape into air. Spontaneous combustion results, and a beautiful ring of white smoke is produced.
2. Keep a quantity of the gas over water for a few days.

Properties: When prepared by the first of the above methods the gas is not spontaneously inflammable. It possesses a strong offensive odor, like garlic; is slightly soluble in water; and burns with a brilliant white flame. It is analogous to ammonia in some of its chemical relations. Its combustion may be symbolized as follows:

$$PH_3 + 2\ O_2 = H_3PO_4.$$

Test: Its flame; its odor; and its spontaneous inflammability when prepared by the second of the above methods. The gas loses this property when kept standing over water for some time.

EXERCISE.

1. What weight and volume of phosphine can be obtained from 41 grams of phosphorous acid?
Ans. 4·25 grams; 2·8 litres.

2. What volume will 51 grams of the gas occupy?
Ans. 33·6 litres.

3. If 28 litres of phosphoretted hydrogen be decomposed into its constituent elements, what volume will they occupy in the gaseous condition at the standard temperature and pressure? A. 4 litres of P; and 24 of H.

4. If 56 litres of phosphine be burned in oxygen, what compound and what weight of it will be produced?
Ans. 225 grams of H_3PO_4.

5. What weight of metaphosphoric acid can be formed from 38·5 grams of phosphorus pentoxide? Ans. 40 grams.

EXERCISE.

What is the percentage composition of each of the following named substances :

1. Arsenious oxide, As_2O_3.
   Ans. 75·75 arsenic ; 24·25 oxygen.
2. Chloride of gold, $AuCl_3$.
   Ans. 35·14 gold ; 64·86 chlorine.
3. Arseniuretted hydrogen, AsH_3.
   Ans. 96·15 arsenic ; 3·85 hydrogen.
4. Potassium ferrocyanide, $K_4\ FeC_6N_6$.
   Ans. 42·45 potassium ; 15·2 iron ; 19·55 carbon ; 22.8 nitrogen.
5. Epsom salts, $MgSO_4$.
   Ans. 20 magnesium ; 26·67 sulphur ; 53·33 oxygen.

EMPIRICAL FORMULÆ.

A substance upon analysis yields the following percentage composition : Potassium, 28·73 ; hydrogen, 0·73 ; oxygen, 47·2 ; sulphur, 23·52. Calculate its empirical formula.

To solve this and all similar problems observe the following rule :

1. Divide the percentage amount of each constituent element by its own atomic weight.

2. Divide each of the quotients thus obtained by the lowest of them.

3. Reduce this second set of quotients to their simplest ratios, and the numbers obtained will express the number of atoms of each element in the compound.

In solving the above question proceed as follows :

Potassium.......... 28·73 ÷ 39·1 = ·73
Hydrogen.......... ·73 ÷ 1 = ·73
Oxygen........... 47·02 ÷ 16 = 2·93
Sulphur .... 23·52 ÷ 32 = ·73

Now the smallest of these quotients is ·73, and dividing each of them by this, we obtain one for K, one for H, one for S, and four for O. The empirical formula is, therefore, $KHSO_4$, and the substance is hydro potassic sulphate.

The problems in the following exercise can all be solved in a similar manner.

EXERCISE.

Calculate the empirical formula and name the substances which yield upon analysis the following percentages of the elements named.

1. Carbon, 42·86 ; oxygen, 57·14.
Ans. CO, carbon monoxide.

2. Hydrogen, 2·73 ; chlorine, 97·27.
Ans. HCl, hydric chloride.

3. Hydrogen, 83 ; sodium, 19·17 ; sulphur, 26·66 ; oxygen, 53.33.
Ans. $HNaSO_4$ hydro sodic sulphate.

4. Sodium, 39·31 ; chlorine, 60·69.
Ans. NaCl, sodic chloride.

5. Nitrogen, 82·35 ; hydrogen, 17·65.
Ans. $NH._3$, ammonia.

6. Phosphorus, 91·17 ; hydrogen, 8·83.
Ans. PH_3 phosphine.

7. Carbon, 26·67 ; hydrogen, 2·22 ; oxygen, 71·11.
Ans. $C_2H_2O_4$, oxalic acid.

8. Carbon, 75 ; hydrogen, 25. Ans. CH_4 marsh gas.

9. Carbon, 12 ; calcium, 40 ; oxygen, 48.
Ans. $CaCO_3$, calcic carbonate.

MISCELLANEOUS EXERCISE.

1. 30 litres of hydrogen are mixed in a flask with 20 litres of oxygen. Which gas remains in excess after explosion, and how many litres of steam are produced?

Ans. 5 litres O remain; 30 litres of steam.

2. Mix 10 litres of hydrogen with 15 of chlorine, and calculate the total volume of the gases after explosion.

Ans. 20 litres HCl; 5 litres of Cl.

3. A certain volume of sulphuretted hydrogen required for its combustion 75 litres of oxygen. Find that volume, and also the weight of the substance produced.

Ans. 50; and 183 grams of H_2SO_3.

4. Assuming that $\frac{1}{5}$ the volume of air is oxygen, calculate how many litres of air it will take to burn 20 litres of (*a*) carbonic oxide, (*b*) phosphine, (*c*) olefiant gas.

Ans. 50; 200; and 300 litres respectively.

5. If 10 volumes of carbon dioxide be passed over red hot charcoal, what gas and how many volumes of it will be formed? Ans. 20 vols. of CO.

6. 25 volumes of steam are passed into a tube containing red hot iron filings, what gas will pass out, and how many volumes of it? Ans. 25 vols. of H.

7. A series of electric sparks passed into a 20 litre jar of ammonia gas decomposed it. Find the volume of the constituent gases. Ans. 5 litres of N; and 15 of H.

8. 24 grams of carbon are burned in oxygen gas. Find the volume of the gas produced. Ans. 44·8 litres.

9. 80 grams of sulphur are made to burn in 56 litres of nitrous oxide gas. Find the resulting volume of gas formed, and the volume (if any) of nitrous oxide remaining.

Ans. 56 litres SO_2 formed; and 56 litres of N.

10. How many litres of oxygen and nitrogen respectively can be obtained from 30 litres of nitrogen tetroxide?

Ans. 10 of N ; 20 of O.

11. How many cubic inches of hydrogen and nitrogen respectively can be obtained from one litre of ammonia gas?

Ans. 15·25 N ; and 45·77 of H.

12. If 10 litres of oxygen be united with 5 of sulphur vapor, what will be the volume of the resulting compound gas at standard temperature and pressure.

Ans. 10 litres.

CHEMICAL ANALYSIS.

This subject admits of a two-fold division, viz., into :

(1) **Qualitative analysis**, whose object is the discovery of the metals, bases, and acids that compose a given compound.

(2) **Quantitative analysis**, whose aim is the determination of the relative weights in which such metals, bases and acids occur, in the given compound.

The first operation is comparatively easy, especially in so far as all the common metals are concerned ; the second is somewhat difficult, and can only be carried on in a well-equipped laboratory, if strictly reliable results are desired.

PRELIMINARY OPERATION.

The substance presented for analysis may be in the solid, or in the liquid form. If solid, the student may begin to examine it as follows, simply remembering that the results obtainable in this way are not trustworthy, but that they are valuable because they often furnish hints regarding the kind of ingredients composing the analytical specimen.

HEAT THE SOLID SUBSTANCE IN A GLASS TUBE CLOSED AT ONE END.

A. It Fuses.	B. It does not Fuse, but changes Colour.	C. It evolves Gas.	D. It forms a Sublimate.	E. Drops of Water are formed.
Alkaline salts **It fuses, and changes colour.** Colour while — Hot, Cold Bismuth oxide. — Hot: *yellow*, Cold: *dark yellow* Lead oxide, — Hot: *yellow.* Cold: *dark red.* If the substance blackens, organic matter is present, and the analysis is too difficult for young students.	Before heating. / While hot. Zinc oxide — *white.* / *yellow.* Stannic oxide, — *straw.* / *dark yellow.* Ferric oxide, — *brown red.* / *black.* Mercuric oxide. — *red.* / *brown red.*	1. Gases are colourless and odourless, a. *Oxygen.* Easily decomposed peroxides, chlorates and nitrates. b. *Carbon monoxide.* Oxalates. 2. Gases are colourless, but possessed of an odour. a. *Ammonia.* Ammonium salts. b. *Sulphur dioxide.* Sulphites and certain sulphates c. *Cyanogen.* Cyanogen compounds 3. Gases are coloured. a. *Brown red—nitrous oxide.* Nitrites and certain nitrates of the heavy metals.	1 *Reddish brown drops.* Sulphur. 2. *White sublimate.* Ammonium salts, mercurous and mercurie chlorides, arsenious and antimonious oxides. 3. *Yellow sublimate,* Mercuric iodide, arsenious sulphide. 4. *Orange yellow sublimate, changing to black on heating.* Mercuric sulphide. 5. *Metallic mirror.* Arsenic. 6. *Metallic globules.* Mercury.	1, *Water of crystallization, reaction, generally neutral.* Easily fusible salts. 2. *Water of combination.* Generally non-fusible salts. a. *Water reacts acid.* Sulphites, chlorides, &c. b. *Water reacts alkaline.* Ammonium salts.

NOTE.—This table is from Thorpe and Muir's Qualitative Analysis.

SECOND OPERATION.

Powder a piece of the assay and prepare three solutions of it :—

(1) By boiling in distilled water.

(2) By boiling in hydrochloric acid.

(3) By boiling in nitric acid, or in acqua regia.

NOTE.—If no solution can be obtained, a more advanced work on chemical analysis must be consulted.

Now all solutions of metals and bases may be arranged into four large classes or groups, by the effects produced upon such solutions by treating them with certain other solutions, called group re-agents. The usual group re-agents, or group tests, as they are sometimes called, are the following :—

I.—Sulphuretted hydrogen added to an acid solution of the assay.

II.—Ammonium sulphide to an alkaline solution—ammonia being first added to insure alkalinity, and ammonium chloride to prevent the precipitation of magnesium compounds.

III.—Hydro di-sodic phosphate to an alkaline or neutral solution—ammonia and ammonium chloride having been previously added.

IV.—The test for this group is the absence of any precipitate through the agency of any of the preceding re-agents.

FAMILIES.

These four groups of metals or bases may be further classified into families. For example, Group I. may be subdivided as follows :—

1. **Family, precipitated white** by HCl, the precipitate being permanent.

Members : Ag, Pb, Hg (-ous, that is, mercury as a sub-salt).

2. **Family, precipitated yellow** from a solution, acidified with HCl, by SH_2.

   Members : As, Sn (-ic) Cd.

3. **Family, precipitated brown** from the acidified solution, by H_2S.

   Member : Sn, as a stannous compound.

4. **Family, precipitated orange** from acidified solution by H_2S.

   Member : Sb.

5. **Family, precipitated black** from acidified solution by H_2S.

   Members : Pb, Hg, Cu, Bi, Au, Pt.

The three solutions, prepared as directed above, should each be treated by the group re-agents. As soon as the group to which the base or metal belongs has been determined, the family and the individual element can easily be made out, by applying the proper tests.

The operations indicated above may be tabulated as follows :—

ANALYTICAL TABLE OF FIRST GROUP, AND ITS FIVE FAMILIES.

Acidify with HCl.															
A. **White** precipitate, not soluble in excess of the acid First family. To this precipitate add NH_3			B. No precipitate. Pass H_2S into the solution for some time.												
The precipitate.			1. Milkiness	2. **Yellow** precipitate. Second family. To this precipitate add NH_3				3. **Brown.** Third family.	4. **Orange.** Fourth family.	5. **Black** precipitate. Fifth family. To portions of the original solution add					
(*c*)	(*b*)	(*a*)		(*b*) Precipitate dissolves. To original add $AgNO_3$ and NH_3.		(*a*) Precipitate remains. To original add KHO in excess.				(*a*) H_2SO_4	(*b*) KHO	(*c*) NH_3	(*d*) H_2O	(*e*) Sn_2Cl_4	
Remains .... Pb	Blackens .... Hg (-ous)	Dissolves .... Ag	Denotes separated sulphur.	Yellow ppt.. As (-ous)	Red ppt..... As (-ic)	Ppt. forms & dissolves .. Sn (-ic)	Ppt. forms & remains .. Cd	.... Sn (-ous)	.... Sb	White ppt. ...... Pb	Yellow ppt....... Hg (ic)	Blue solution .... Cu	White ppt. ...... Bi	Purple ppt. ...... Au	Red solution .... Pt

GROUP II.

The second group may be divided into four families as follows :—

1. **Family, precipitated white** from an alkaline solution, by NH_4HS.

Members: Zn, Al.

2. **Family, precipitated flesh-color** by NH_4HS.

Member: Mg only.

3. **Family, precipitated green** by NH_4HS.

Member : Cr.

4. **Family, precipitated black** by NH_4HS.

Members: Fe, Co, Ni.

The operations necessary to eliminate the members of the second group may be tabulated as follows :—

ANALYTICAL TABLE OF SECOND GROUP, AND ITS FOUR FAMILIES.

<table>
<tr><td colspan="8">Add NH_4Cl, NH_3, and NH_4HS.</td></tr>
<tr><td colspan="2">1.
Family.
White ppt.
To original solution add KHO to excess and then add</td><td>2
Family.
Flesh color ppt.</td><td>3.
Family.
Green ppt.</td><td colspan="4">4.
Family.
Black precipitate.
To the ppt. add HCl freely.
The precipitate.</td></tr>
<tr><td>(a)
NH_4Cl
White.</td><td>(b)
H_2S
White.</td><td></td><td></td><td colspan="2">(a) Dissolves.
To the original add KHO</td><td colspan="2">(b) Remains.
To the original add KHO</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Greenish.</td><td>Reddish.</td><td>Blue.</td><td>Green.</td></tr>
<tr><td>Al</td><td>Zn</td><td>Mn</td><td>Cr</td><td>FeO</td><td>Fe_2O_3</td><td>Co</td><td>Ni</td></tr>
</table>

GROUP III.

The third group is not usually subdivided into families, and consists of the following members: Mg, Ca, Sr, Ba.

ANALYTICAL TABLE. GROUP III.

<table>
<tr><td colspan="4">Add NH_4Cl, NH_3, HNa_2PO_4. Ppt. White.</td></tr>
<tr><td colspan="4">To original solution, add $CaSO_4$ solution.</td></tr>
<tr><td colspan="2">(*a*) White precipitate.
To original add H_2SiF_6.</td><td colspan="2">(*b*) No precipitate.
To original add oxalate of ammonia $(NH_4)_2\overline{O}$.</td></tr>
<tr><td>White ppt.</td><td>No ppt.</td><td>White ppt.</td><td>No ppt.</td></tr>
<tr><td>Ba.</td><td>Sr.</td><td>Ca.</td><td>Mg.</td></tr>
</table>

GROUP IV.

This group, as previously remarked, is characterized by non-precipitation through the agency of any of the preceding group tests. It also is not subdivided into families, and consists of only three members, viz., Na, K, and the radicle, NH_4.

ANALYTICAL TABLE. GROUP IV.

<table>
<tr><td colspan="2">Evaporate to dryness, and heat strongly.</td></tr>
<tr><td>(*a*) Volatilizes.</td><td>(*b*) Residue remains.</td></tr>
<tr><td>NH_4</td><td>Na or K.
These may be distinguished by the color they impart to flame; or better still, by the spectroscope.</td></tr>
</table>

EXAMINATION QUESTIONS.

The following sets of questions have been selected from the Elementary Papers on Chemistry given at Queen's College.

I.

1. Describe carefully how the composition of water is determined synthetically and analytically.

2. Taking a molecule of water as a type, explain fully the composition of an acid, a base, and a salt ; give examples. What practical differences are there between these three compounds ?

3. What is meant by a substance in its nascent state and what are its properties ? Give cases in illustration.

4. Give all the chemical changes, where known, and any visible phenomena, when :—(*a*) zinc is put into sulphuric acid ; (*b*) copper is put into nitric acid under a bell-jar ; (*c*) electric sparks are passed through air ; (*d*) potassic chlorate is acted on by hydrochloric acid ; (*e*) wood is heated in close vessels.

5. How would you determine the proportion of oxygen in the air ? How prove that it is not in combination ?

6. Explain the action going on in the several parts of a common flame. What is the effect of too little air upon it ? Of too much air ?

7. What volume of ammonia can be obtained from 100 grams of ammonic chloride.

II.

1. Give the length of a metre in inches, and show its relation to the gram and litre.

2. How many times is the gas Cl_2O_4 heavier than air?
ANS. 4·67.

3. Explain the meaning of the terminations, -ous, -ic, -ide, -ite, -ate.

4. (*a*) Show how to obtain nitric acid. (*b*) Given nitric acid and other necessaries obtain N_2O, N_2O_2, and N_2O_3, giving formulæ.

5. What gas and what weight of it will be obtained by acting on marble by 100 grams of HCl?

6. Benzine burns with a smoky flame. Explain the cause of (*a*) the heat, (*b*) the light, (*c*) the smoke. How may the smoke be prevented?

7. Describe sulphuric acid and explain its formation.

8. If a molecule of water consists of 3 atoms, show that a molecule of hydrogen consists of 2. State Avogadro's law.

III.

1. Give general differences between chemical compounds and mechanical mixtures.

2. Upon what basis does Avogadro's law rest? Shew how from it you can find the density of the gas C_2H_6O.

3. How would you distinguish certainly between;—Oxygen and nitrous oxide; nitrogen and carbon dioxide; hydrogen and carbon monoxide; phosphine and arsine.

4. Show how to obtain liquor ammoniæ. Of what is it a hydrate?

5. Describe Bunsen's burner, and explain its action.

6. You are given "salt," alcohol, manganic dioxide, and sulphuric acid. How will you obtain hydrochloric acid, chlorine, oxygen, olefiant gas?

7. 100 grams of oxalic acid is decomposed by sulphuric acid, and the escaping gases are passed through lime water. What weight of calcic carbonate will be formed?

ANS. 111⅑ grams.

IV.

1. If one volume each of the following gases be burned with oxygen, what gases, and what volume of each will be formed?—marsh gas, olefiant gas, phosphine, hydric sulphide.

2. Give the composition of the following, and state how they are obtained:—ozone, laughing gas, bleaching powder.

3. Give the principal constituents of the atmosphere, with their uses; and show how the relative amounts of oxygen, carbon dioxide, and water-vapour may be obtained.

4. Give the reaction, and products when:—(*a*) zinc is put into hydrochloric acid; (*b*) tin is acted upon by nitric acid.

5. What takes place when:—(*a*) magnesium is heated in air; (*b*) ammonia is added to $CuSO_4$ solution.

6. When does a gas become a vapour, and *vice versa?* State their similarities and differences.

The following questions have been selected from the Examination Papers of Toronto University for the years 1879, 1880, and 1881.

1879.

I.

1. Calculate the density of carbon dioxide from the following data:—Weight of globe full of air, 948 grammes; weight of globe exhausted, 933·5 grammes; weight of globe full of carbon dioxide, 955 54 grammes; assuming temperature and pressure to remain constant during the experiment.

2. Illustrate the laws of chemical combination by means of the compounds of nitrogen with oxygen and hydrogen.

3. What is the usual source of nitric acid? How is it prepared? What weight of each of the materials must be taken to obtain 300 grammes nitric acid?

4. What is meant by "allotropism?" Illustrate with carbon, sulphur and any other element.

5. Give a full description, illustrated by a sketch of apparatus, of the method usually adopted in the laboratory for generating and collecting chlorine. How is liquid chlorine obtained? What are the more important properties of chlorine?

6. What is ozone? How formed? What are its properties?

7. Peroxide of hydrogen. Give its preparation and properties. How distinguished from ozone?

8. What is meant by atomic weight? How is the molecular weight of a substance determined? Give reasons for believing that the molecule of the elements usually contains two or more atoms.

1880.

I.

1. How may the following substances be shewn to be compounds of nitrogen:—Nitric acid; ammonia; cyanogen?

2. Describe a process for the formation of sulphuric acid. Calculate the percentage composition of copper sulphate. $Cu = 63 : S = 32 : O = 16$.

3. Write equations expressing the action of sulphuric acid on each of the following substances: Sodium chloride; sodium carbonate; sodium nitrate; copper.

4. Give the names and formulæ of the principal compounds of phosphorus, and compare them with those of nitrogen.

5. State fully what facts are represented by the equation :

$$C_2H_4 + 3\,O_2 = 2\,CO_2 + 2\,H_2O.$$

Why should it not be written :

$$CH_2 + 3\,O = CO_2 + H_2O\,?$$

6. Describe the preparation of methane (marsh gas). What products are formed by the action of chlorine upon it? To what class of compounds does it belong?

II.

1. State fully what facts are represented by the equation :

$$2\,NO + 2\,H_2 = N_2 + 2\,H_2O$$

Why should it not be written :

$$NO + 2\,H = N + H_2O$$

2. What reasons have we for thinking that the air is a mixture and not a chemical compound?

3. How may each of the oxides of carbon be converted into the other? Calculate the percentage composition of carbon monoxide and of carbon dioxide.

4. What is the law of combination in multiple proportion? Show that the oxides of nitrogen conform to the law.

5. Show how the oxides of lead PbO, Pb_3O_4, PbO_2, conform to the law of combination in multiple proportion ($Pb = 207$).

6. Write equations representing the following reactions :— (*a*) nitric acid on copper : (*b*) sulphur dioxide on nitrogen trioxide and water ; (*c*) maganese dioxide on hydrochloric acid.

1881.

1. Define the meaning of the following terms :—Specific gravity, specific heat, latent heat.

2. Chlorine was formerly regarded as a compound of hydrochloric acid gas with oxygen. Describe experiments proving that this was an incorrect view.

3. How may the following compounds of sulphur be prepared from the element :—Hydrogen sulphide, sulphur dioxide, sulphur trioxide, sulphuric acid, and carbon disulphide.

4. Calculate what weight of zinc will yield 1 gram of hydrogen.

5. Express by equations the following reactions :—(*a*) chlorine on solution of potassium hydrate : (*b*) ammonium chloride on calcium hydrate ; (*c*) heat on ammonium nitrate.

6. The following vapor densities have been recently determined :

Arsenic trioxide..........	10·37	(air = 1)
Cuprous chloride..........	7·05	"
Phosphorus pentasulphide..	7·67	"

Calculate from these figures the molecular weight and formulæ of the substances.

The following questions are from the pass papers of Victoria University, and have been kindly furnished by Professor Haanel, Ph. Dr.

I.

1. Required to make 15 litres of ozone measured at 20°C and 740 mm by the method of passing electric sparks through oxygen. How much oxygen by weight is required ?

2. Calculate the combining equivalents of the elements entering into the constitution of the compound $ZnSO_4$ on the supposition that the combining equivalent of O = 100.

3. Point out the relations existing between the oxygen and sulphur compounds.

4. State the properties of sulphur trioxide, and describe a method of preparing it.

5. Distinguish between chemical and physical changes.

6. Illustrate by an example the effect of insolubility upon the action of chemical affinity.

7. Distinguish between chemical affinity, cohesion and adhesion.

II.

1. What are the grounds for the assumption of the molecular constitution of the elementary gases.

2. In the electric decomposition of water the volume of gas discharged at the positive pole is less than theory requires. Why?

3. Demonstrate the incorrectness of the explanation offered by Sir Humphrey Davy for the luminosity of the middle layer of a candle flame.

4. State fully the facts symbolized by the following equation:

$$(NO)_2 + O_2 = (NO_2)_2.$$

5. How much by volume of SO_2 and O measured at 15°C and 750 mm. pressure is required to furnish sufficient sulphur trioxide which, when combined with the proper amount of water, will form 32 grams of H_2SO_4?

6. A mixture of oxygen and ozone was allowed to bubble through 64 grams of hydrogen peroxide, completely decomposing it, the resultant gas measured 90 litres at 4°C and 763 mm. pressure. How much oxygen by weight did the original mixture contain?

7. Sulphuretted hydrogen was allowed to act upon a sufficient quantity of sulphur dioxide, producing complete decomposition of the gases. The sulphur obtained was found to weigh 15 grams. How much by volume respectively of sulphuretted hydrogen and sulphur dioxide measured at 20°C and 780 mm. pressure entered into the reaction?

III.

1. Reduce 25° Centigrade to Reaumur and to Fahrenheit.

2. State Berthollet's law and illustrate by examples.

3. Illustrate the law of multiple proportions by examples.

4. Distinguish between the combining equivalent and the atomic weight of an element.

5. State the properties of hydrogen and the modes of its preparation, illustrating the latter by diagrams of apparatus used, and representing the reactions taking place by equations.

6. State the properties of nitrogen monoxide, the most convenient mode of its preparation, and prove its volumetric composition to be represented by N_2O.

7. Solve the following questions :

$$\left(\left.\begin{matrix}H\\H\end{matrix}\right\} O\right)_2 + \left.\begin{matrix}K\\K\end{matrix}\right\} =$$

$$4\,Zn + 2\,(HNO_3) + 4\,(H_2SO_4) =$$

$$9\,(HNO_3) + (H_2O)_x + 4\,Zn =$$

$$Cu + 2\,(H_2SO_4) =$$

8. How much Cu is required for the evolution of 75 litres of nitric oxide from HNO_3 – temp. = 40°C press. = 650 mm. ? Cu = 63·5.

9. A mixture of O and N when transferred to a Hoffman's Eudiometer measured 30 cc. After the addition of H the volume was found to be 46·2 cc. After explosion by the electric spark the remaining volume measured 32 volumes. How much O in weight was originally present in the mixture, the temperature and pressure remaining constant at 0°C and 760 mm. ?

N.B —In working the examples state clearly what each quantity represents.

INTERMEDIATE EXAMINATION.

JULY, 1880.

1. Describe the chief characters of (1) ammonia, (2) ammonium carbonate; and the process by which they are usually prepared. Give also the chemical reactions which occur in these processes.

2. Describe fully the modes of decomposing water which you have seen. State how you would determine whether a given specimen of water is hard or soft. If the water is found to be hard, state (with reasons) the various means by which it could be made soft.

3. What means are best employed for the collection of nitric oxide, chlorine, ammonia, carbonic acid, sulphur dioxide, and nitrous oxide gasses.

4. Describe fully the experiment in which the reactions are given by the equation.

$$CaCO_3 + 2\ HCl = CaCl_2 + H_2O + CO_2.$$

5. Describe some of the properties of sulphur, and state its allotropic modifications, and how they are obtained. Sulphur is said to be a *dimorphous* body—explain.

6. Calculate the percentage composition by weight of potassium nitrate, and of the two oxides of carbon.

7. Write down the atomic weight, the molecular weight, the relative weight, the specific gravity, the atomic and the molecular volume of chlorine, and fully explain the meaning of these terms.

8. On completely decomposing by heat a certain weight of potassium chlorate, 20·246 grains of potassium chloride was obtained. What weight of potassium was used, and how much oxygen was evolved?

JULY, 1881.

1. $KNO_3 + H_2SO_4 = HNO_3 + KHSO_4$. (1.) Give, first, the names of the compounds entering into the reaction represented by above equation, and, second, the names of the elements, with their combining weights, entering into the constitution of these compounds. (2.) Represent, by diagram, the necessary apparatus for conducting the experiment indicated by the equation. (3.) What effect would H_2SO_4, HNO_3 and KNO_3, each have upon a solution of blue litmus?

2. It is required to make $3\frac{1}{2}$ pounds of HNO_3 by experiment 1. (2). How much H_2SO_4 is required?

3. Explain the principle of Davy's safety lamp.

4. It is required to prepare the elements hydrogen and nitrogen for class purposes: (1.) Describe the apparatus and name the substances needed for the preparation of each of the elements. (2.) Write out the equations representing the reactions occurring in their elimination. (3.) Describe the experiments you would perform to demonstrate their distinguishing properties.

5. Assign reasons for assuming that charcoal, graphite and diamond, are different modifications of the same element.

6. Complete the following equations:

$CaCO_3 + 2\,(HCl) =$
$Na + H_2O =$
$2\,(NaCl) + 2\,(H_2SO_4) + MnO_2 =$
$P_2O_5 + 3\,(H_2O) =$

7. Coal gas and phosphorus burn with a luminous, sulphur and hydrogen with a non-luminous flame. Account for this difference.

8. A certain quantity of zinc furnished, when treated with sulphuric acid, $3\frac{3}{4}$ pounds of zinc sulphate. How much zinc was employed? $Zn = 65$.

JULY, 1882.

1. A specimen of water was divided into two parts. One part was then boiled for some time. To this and the unboiled portion, contained in separate bottles, a small quantity of finely powdered chalk was added. Upon agitation it was found that the boiled portion had become milky, the unboiled portion remained clear, the chalk having dissolved. Explain the cause of this difference.

2. How much sulphur dioxide, by weight, can be obtained by burning 25 grains of sulphur in sufficient oxygen?

3. Which of the following gases should be collected by *upward* and which by *downward* displacement: Chlorine, carbon dioxide, hydrogen, sulphur dioxide, ammonia?

4. A quantity of alcohol, contained in an evaporating dish, was ignited and the burning liquid poured through wire gauze held over a beaker. The flame was by this process confined to the upper surface of the wire gauze, and the greater part of the alcohol collected unignited in the beaker. State the principle upon which the success of this experiment depends.

5. Assign reasons for assuming that the atmosphere is not a chemical compound but a mechanical mixture of oxygen and nitrogen.

6. Describe the physical changes which sulphur undergoes in being heated to 440°C.

7. Write out the equation representing the reaction taking place in the preparation of nitrogen dioxide, and represent by diagram the necessary apparatus for its elimination and collection.

8. A piece of paper saturated with spirits of turpentine when plunged into a jar containing dry chlorine ignites. Explain.

9. (i.) Write out the equation representing the reaction in preparing the carbon dioxide from calcium carbonate and hydrochloric acid.

(ii.) How much, by weight, of calcium carbonate is required to furnish 12 litres of carbon dioxide, measured at 0°C and 760$^{mm.}$ P. ?

JULY 1883.

1. State the law of multiple proportions, and explain your statement by examples.

2. Give the atomic weights ($H = 1$,) of oxygen, nitrogen, carbon, chlorine, sulphur and phosphorus; and calculate the molecular weights of ammonia, light carburetted hydrogen, sulphuretted hydrogen, nitrous oxide, carbon dioxide, phosphorus pentoxide, nitric acid and sulphuric acid.

3. Describe a process of preparation and the chief properties of hydrogen.

4. What are the chief properties of oxygen? Give the equations for four processes for the preparation of oxygen, and describe one of these processes.

5. Describe the preparation and properties of carbon dioxide. What are the chief properties of a solution of carbon dioxide in water?

6. Describe the product of combustion of sulphur in air. In what respect does its bleaching power differ from that of chlorine?

7. Express by symbols the reactions which occur when sulphuric acid is heated together with *(a)* common salt, *(b)* sal ammoniac, *(c)* nitre, *(d)* copper.

JULY, 1883.

FIRST CLASS TEACHERS—GRADE C.

1. Explain the full meaning of the following, merely as chemical symbols :—O, OH_2, $3\ Na_2\ CO_3$.

2. The chemical constitution of a gas being known, how can you calculate its specific weight?

Apply your method to find the sp. wt. of the gases whose compositions are—CO_2, NH_3, $C_4H_{10}O$.

Can you mention any gases which form an apparent exception to the general rule?

3. The ultimate analysis of a substance composed of carbon, hydrogen, and oxygen, gives, in one hundred parts—carbon, 40; hydrogen, 6.6; oxygen, 53.4, by weight, and the specific weight of its vapor is 30. Determine the formula of the substance.

4. Describe the usual methods of obtaining the following substances, and in all cases illustrate by symbols any chemical changes taking place:—*a*) Hydrogen, (*b*) nitrogen monoxide, (*c*) chlorine, (*d*) sulphur dioxide, (*e*) sodic carbonate, (*f*) "quick" lime, (*g*) magnesic sulphate, (*h*) ferric chloride.

5. Describe and explain any phenomena observable, when—

(*a*) Copper is put into strong nitric acid;

(*b*) Water is mixed with strong commercial sulphuric acid;

(*c*) The breath is passed for some time through lime-water, and then carbon dioxide is passed through it in excess.

(*d*) A few drops of sulphuric acid is added to a solution of sodic thiosulphate.

(*e*) Ferrous sulphate is strongly heated in the air.

(*f*) A drop of a solution of potassic permanganate is added to water containing organic matter.

6. What is the chemical difference in the bleaching effected by chlorine and that by sulphur dioxide?

Dry chlorine will not bleach. Why?

7. Name the essential constituents of the atmosphere, and give, as far as you can, their particular uses in the economy of nature.

INDEX.

PAGE.
Autylene 48
Atomic Theory 5
Atom 9
Atomicity 14
Atomicity, Table of 15
Acids 25
Avogadro's Law 30
Atmosphere 39
Ammonia 32
Ammonium hydrate 33

Binary compounds 24
Bases 26
Bleaching powder 59

Chemical analysis 77
Chemical compounds 7
Chemism 10
Chemical combination 13
Chemical combination, Laws of 13
Carbon 40
Carbon monoxide 42
Carbon dioxide 43
Coal gas 51
Combustion 51
Chlorine 54
Chlorine and oxygen 59
Chloric acid 60
Carbon disulphide 66
Cyanogen 50

Density 17

Elements 6
Equation, Chemical 12
Ethene, or Ethylene 48
Examination Questions 85
Empirical formula 73

PAGE.
Formula 11
Flame structure 52

Gram, weight 17

Halogens 54
Hydrogen 18
Hydrates or Hydroxides 25
Hydrochloric acid 56

Inorganic chemistry 5
Impurities of water 28

Liquor ammoniæ 33
Litre 16

Metals 6
Mechanical mixture 7
Molecule 9
Metre 16
Metric system 16
Marsh gas 46

Non-metals 6
Notation, Chemical 10
Nomenclature 24
Nitrogen 30
Nitrous oxide 34
Nitric oxide 35
Nitrogen trioxide 35
Nitric acid 36
Normal Salt 63

Organic chemistry 5
Oxygen 21
Ozone 22
Oxygen and nitrogen 34
Olefiant gas 48

Physical states of matter 8
Potassic chlorate 60

PAGE
Phosphorus 67
Phosphorus trioxide 69
Phosphorus pentoxide 70
Phosphoric acid, "glacial" 70
Phosphoretted hydrogen 71
Radicles 16

Symbol 10
Specific weight................. 17
Salts...... 26
Sulphur 60

PAGE.
Sulphur dioxide 61
Sulphuric acid 62
Sulphuretted hydrogen 64

University Exam. Questions 85

Volume 10
Valency 14

Water 28

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